Idleply

a concept for the future of OLED lighting

Henrik Amberla
MA Thesis

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Department of Design
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Abstract

In this thesis, I document the creation of a concept OLED luminaire called Idleply. My thesis is also a study on the state of OLED lighting today, in the future and in relation to the past. I give an account of what OLED lighting is and how it differs from other forms of lighting. A glossary of lighting-related terminology is provided in the early pages.

The basis for a design approach is laid in a review of how lights design has changed in the past whenever new technologies have been introduced, the three most important examples being incandescent light bulbs, fluorescent tubes and halogen lamps. Not surprisingly, the past has favored practicality over style in the mass adoption of lighting solutions. This question is at the very core of modernist thinking and still as relevant for designers as ever. The future predictions that I present about OLED lighting are based on market research articles, corporate roadmaps and my own experience. The future success and mainstream popularity of OLED lighting is to a great extent dependent on cutting down manufacturing costs and increasing energy-efficiency, as well as good design.

The thesis describes the design process of Idleply and the making of the prototypes. The luminaires are tall, flat and flexible indoor floor lights that can be bent to almost any desired shape. Instead of actual OLED panels, I have used electroluminescent sheet to illustrate OLED functionality. Because the light source is a surface, the smooth light is friendly to the eye and causes very little glare. Idleply is a design that wouldn't be possible without flexible surface lighting and it anticipates a time when such designs are commonplace. I conclude the thesis by reviewing what could be improved in my own work and by taking a look at how others have approached the same themes that I have.

Acknowledgements

During the first months of my thesis work I had the privilege to be employed by Aalto Lighting Unit as a research assistant in the research project AthLEDics, which focuses on designing, implementing and testing advanced technologies for energy efficient LED lighting applications to satisfy user needs (AthLEDics 2010). This great opportunity was made possible by my two thesis supervisors, professor of Industrial and Strategic Design Raimo Nikkanen and research scientist at Aalto Lighting Unit, D.Sc. Eino Tetri. I would like to thank both for their supervision and persistent support throughout the thesis process.

I am grateful for all the guidance and encouragement provided by the staff of Aalto University as well the diverse facilities that the university provides for its students for carrying out their projects.

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Glossary

GENERATING LIGHT

AMOLED (Active-matrix organic light-emitting diode) is a display technology prominently used in high-end smartphones. "Active matrix" refers to the technology that is used to address the individual OLED pixels as opposed to a "passive matrix" in PMOLEDs. A passive-matrix OLED display is cheaper to produce, but has notable size and resolution restrictions.

Chemiluminescence is the emission of light as a result of a chemical reaction. Chemiluminescence is used as an indicator in many biological and chemical analyses and in party decorations, such as glow sticks.

Doping semiconductors refers to the intentional introduction of impurities in the semiconductor material. Dopants are instrumental in creating a PN junction in the semiconductor chip within an LED. Correct selection of dopants depends on the semiconductor material used and the desired wavelength output. In LED technology, dopants are categorized into N-type (negative for the cathode) and P-type (positive for the anode) dopants. N-type dopants that result in a negatively charged semiconductor material include carbon, nitrogen, and phosphorus. P-type dopants include aluminium, gallium, indium and tin.

Electroluminescence (EL) is the emission of light from a material in response to an electric current that is passed through it or in response to a strong electric field. The light is not an indirect result of heat caused by electricity like in the case of incandescent light bulbs, but a more direct effect of electricity. OLEDs and LEDs are based on the working principle of electroluminescence which is supplemented with fluorescence or phosphorescence by a coating on the semiconductor material.

Fluorescence is the immediate emission of light by a substance that has absorbed electromagnetic radiation. It is a form of photoluminescence. The light emitted by fluorescent materials has normally a longer wavelength and therefore a lower energy than the absorbed light. In intense radiation, however, the emission can have a shorter wavelength than the absorption. Fluorescent lamps contain a phosphor that is made to fluoresce by ultraviolet radiation from electrically excited mercury vapor. Minerals that glow under an ultraviolet light are a striking example of fluorescence. In white LEDs, the blue electroluminescent light from the semiconductor strikes phosphors that fluoresce the short-wavelength blue light to longer green and red wavelengths causing a white combination (Bush 2008).

Incandescence is glowing as a result of heat. It is the emission of visible electromagnetic radiation from a hot body as a result of its temperature. Old-fashioned light bulbs light up as a result of incandescence in the tungsten filament.

LEDs are semiconductor light sources widely used as indicator lights in electronics and increasingly as light sources in spatial illumination. An LED is a specialized type of PN junction diode, meaning that it contains a semiconductor chip that has a negatively charged side (cathode) and a positively charged side (anode). The positive and negative charges are achieved via doping the semiconductor material with impurities.

Luminescence is the emission of light from a substance not resulting from heat. It is a form of cold body radiation and can result from several causes such as chemical reactions or electrical energy.

OLED (Organic light-emitting diode) is a technology that can be used to make flat, flexible, transparent, bright and energy-efficient displays as well as lights. In an OLED, electricity is passed through very thin layers of organic compound semiconductor material, which then lights up as an outcome of the resulting energy flow.

Organic compounds are a very large class of chemical compounds whose molecules contain one or more carbon atoms. For historical reasons, some exceptions are considered inorganic, such as carbon monoxide, carbon dioxide, carbonates, cyanides, cyanates, carbides, and thyocyanates. Organic compounds can be classified into natural and synthetic compounds. For example, proteins, fats and most sugars are natural organic compounds while most plastics and rubbers are synthetic organic compounds. 95% of all over 60 million known chemical compounds are organic compounds (CAS 2012).

PHOLED (Phosphorescent organic light-emitting diode) is one type of OLED technology where the use of phosphorescent materials aims to obtain higher efficiencies than in fluorescent OLEDs.

Phosphors are substances that exhibit the phenomenon of luminescence. Phosphors include both phosphorescent materials and fluorescent materials. The chemical element named phosphorus emits light via chemiluminescence and it is not a phosphor, although it's named after its light-emitting behavior. In LEDs and OLEDs, the semiconductor can be coated with phosphors to increase the light output and to modify the colour of the light.

Phosphorescence is a specific case of photoluminescence related to fluorescence. Phosphorescent materials show a slow decay in brightness as they have a slower time scale in re-emitting the absorbed radiation than fluorescent materials. "Glow-in-the-dark" phosphorescent materials make use of the slow re-emission of light.

Photoluminescence (PL) is the emission of light from a material as a result of absorbing photons (electromagnetic radiation) and then re-radiating photons. It is distinguished from other forms of luminescence by direct excitation by photons (IUPAC 2011, p.1119).

P-OLEDs (Polymer OLEDs) are OLEDs made with large-molecule materials as opposed to SM-OLEDs (small-molecule OLEDs). They are solution processable, which enables the affordable methods of production inkjet printing and spin-coating. However, almost all OLEDS today are based on the evaporable and far more advanced SM-OLED materials and much research is invested in making them solution-processable.

A **Semiconductor** is a solid material with electrical conductivity between that of a conductor and that of an insulator. The conductivities of different semiconductors can be controlled over wide ranges, either permanently or dynamically. Light-emitting diodes are semiconductor light sources.

Solid-State Lighting means different types of light-emitting diodes as light sources and excludes electrical filaments, plasma and gas as sources of illumination. The term "solid-state" refers to the absence of moving parts and states of matter other than solid.

MEASURING LIGHT

Candela, symbol: cd, is the SI unit for measuring the luminous intensity of a light source in a given direction. Much like the lumen, it is used to indicate the brightness of a light source. It is the base SI unit from which other photometric SI units are derived. In normal conditions, one candle has roughly the luminous intensity of one candela. The operational definition of one candela is the emission of monochromatic 540×10^{12} hertz radiation from a light source with the radiant intensity of 1⁄683 watt per steradian.

Linked to other light measures, one candela is the luminous flux of one lumen over the solid angle of one steradian. The maximum solid angle in space - a sphere - measures $4\pi \approx 12.56637$ steradians. Therefore, a 12.56637-lumen light source that radiates equally in all directions has the luminous intensity of one candela.

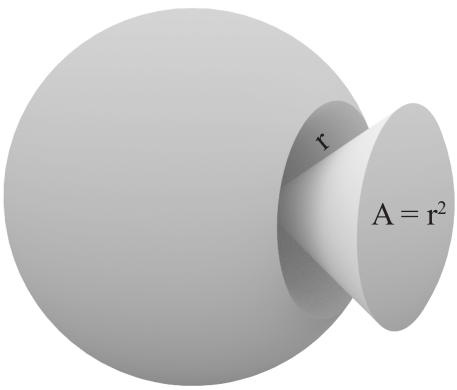


Figure 1 - One steradian cuts out the surface area of radius² from a sphere.

Candela per square metre, symbol: cd/m², is the SI derived unit of luminance. Another, non-SI, name for this measure is nit (nt). The brightness of surface light sources, such as displays, televisions and OLEDs are often indicated in cd/m². For example, many consumer LCD displays have luminances of 250 to 300 candela per square metre (Busch 2006).

Colour Rendering Index (CRI) is a quantitative measure of the ability of a light source to reproduce the colours on the objects that it illuminates. In photography, cinematography and art, light sources with a high CRI are desired to ensure high quality outcomes. OLEDs still struggle to reach CRIs over 90 while incandescent light bulbs are rated at a full 100. The standard Ra method for measuring CRI is very complex and doesn't always produce an accurate measure in solid-state lighting. New methods have been developed but they haven't yet been widely adopted.

Kelvin, symbol: K, is conventionally used as a measure for the correlated colour temperature of a white light source. It's based on the theoretical principle that a black body radiator emits light whose colour depends on the radiator's temperature. Below 4000 K, lights appear reddish and above 7500 K, they appear bluish. Noon sunlight is about 5500 K in colour temperature (Bargh 2002).

Lumen, symbol: lm, is the SI derived unit for luminous flux. Luminous flux means the total amount of visible light emitted by a light source. For example, the lighting power of compact fluorescent light bulbs is often expressed in lumens on the packaging. A 25W compact fluorescent bulb puts out around 1700 lumens.

Lumens per watt, symbol: lm/W, is a SI derived measure of luminous efficacy. How well a light source produces visible light is measured in the ratio of luminous flux (lumens) to power (watts). The theoretical maximum possible efficacy is 683lm/W. Typical 60W incandescent bulbs operate at a luminous efficacy of about 14 lm/W while comparable compact fluorescent bulbs may operate at 57 lm/W.

Lux, symbol: lx, is the SI derived unit of illuminance and luminous emittance. It measures luminous flux per unit area. One lux is equal to one lumen per square metre. Concentrated into an area of one square metre, a light of 1000 lumens will light up that area to an illuminance of 1000 lux. Spread out over ten square metres, the same light will produce only 100 lux. The measure is used when planning the lighting of architectural spaces.

Introduction

The recent and ongoing downfall of the incandescent light bulb has been a global inspiration for industrial designers to both make the most of the perishing old tungsten filament and to create solutions to replace the bulb with more modern solutions. Compact fluorescent lamps have already been adopted by many as an easy and energy-efficient alternative and LED lamps are increasingly finding their way to shop shelves. These incremental improvements will go on to increase the energy-efficiency of household lighting, but can hardly be called a revolution in illumination. After all, replacing a bulb with another bulb does very little to change the practical attributes of the luminaire. The renunciation of incandescent bulbs hasn't yet resulted in any disappearance of Edison's ancient screw fitting or the transformation of lamps into forms that make better use of the new technological solutions.

In engineering laboratories of today and in the interiors of tomorrow, a new lighting solution is making progress. Organic light-emitting diodes promise not only energy-efficiency surpassing contemporary LED lights, but diffuse surface light emitted from thin and flexible layers of smooth transparent plastic. As the very strength of OLED technology is the redundancy of diffusers and reflectors, a larger-scale adoption of the technology would force a new architecture and a form language into the design of lights.

Most attempts to design OLED lights during the past three years have been largely guided by the forms of available light modules, not least because many of these attempts have been funded by module-producing businesses. The engineering-based product development and research employs hundreds of scientists in companies that manufacture OLEDs and aim ambitiously to improve their products. It will be fascinating to see what results the large research investments will yield in the coming years, but it is also important for designers to take an active role in forecasting the shape of future lighting.

When future isn't available, concepts have to be designed. In addition to mapping out the state of OLEDs today and taking a look at what may be happening in the future, my thesis consists of placing OLEDs in a historical context and taking a look at how new lighting technologies have affected design practice in the past. Another major part of my thesis is the designing and prototyping of an OLED concept luminaire. The concept illustrates benefits and potential uses of OLEDs in interior illumination. Because actual OLED light sources are limited in size and availability, my prototype makes use of electroluminescent sheet that is also a flexible and thin surface light source.

Research questions that I seek answers to are: How can a design perspective contribute to the development of OLED lighting? What kinds of new possibilities does OLED technology give to lights design? What are the biggest practical benefits of OLED lighting? What are the limitations of OLEDs in designing lights? How is OLED positioned in the historical continuum of lights design?

OLED in the Historical Context

To design an OLED light is not just to design an OLED light. By placing my work in a historical context I attempt to shed light on how a new technology such as OLED can advance the design of spatial illumination and alter our perception of artificial light. It is important to understand the past to be able to design for the future. Especially when dealing with such a universal issue as light, designers can't afford to only set their work in a contemporary context.

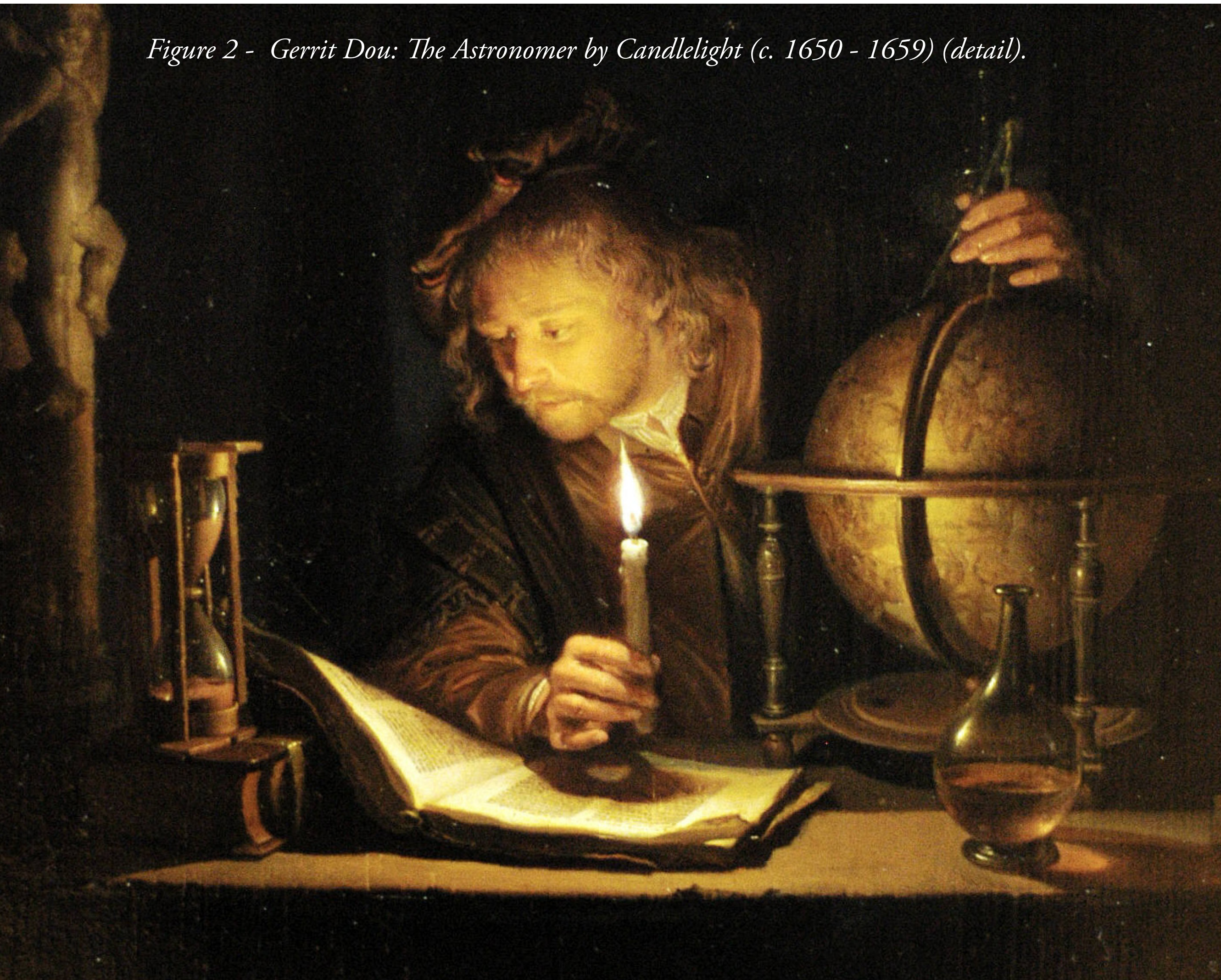


Figure 2 - Gerrit Dou: The Astronomer by Candlelight (c. 1650 - 1659) (detail).

HOW NEW TECHNOLOGIES HAVE AFFECTED LIGHTS DESIGN IN THE PAST

The history of lights design is a narrative of technological advancements in the field of illumination. Inventions and innovations are always more numerous in any technological field than the actual adopted technologies that can be called advancements in the cultural sense. Many ideas fail, and for very different reasons, but most commonly because switching from the old to the new doesn't seem worth the effort. The favorable factors that make efforts worthwhile change with time and culture and cause new technological phenomena to spring up and possibly get adopted by a main stream of users. It'll take years until OLEDs are versatile, affordable and reliable enough for large-scale manufacturing and while waiting for the conditions to change and humbly contributing to the field, it is constructive to try and recognize some prominent waypoints on the path from torches to OLED prototypes.

The Advent of the Incandescent Bulb

The greatest revolution in lights design was the invention and popularization of the incandescent light bulb. Since the early decades of the 20th century until the present time, luminaires based on Edison's light bulb have been the norm in domestic interior illumination. The light bulb's popularity only happened on a larger scale in the wake of the electrification of regular homes. Before electricity became available to average households, there were gas lamps. Gas lamps were preceded by oil lamps, which in turn were preceded by candles and torches of different materials. In short, incandescence via electricity was preceded by fire via burning material.

Lamps and light fixtures based on fire provided much less light than electric lights. In addition, the light source itself was literally burning hot and in most instances flickering and unstable in nature. Many possibilities and restrictions that came with the electric light bulb weren't present with fire-based illumination. Although many oil lamps and some gas lamps already employed lamp shades to reduce glare and to distribute light more efficiently, the light bulb made the task of designing a light fixture most of all a task of designing the shade. Dutch designer Gijs Bakker expressed in 1991, that light bulb manufacturers had done the most important work and what remained for the designers was to simply dream up ways to conceal the bulb (Koch 1994, p.10).

Figure 3 - An early Edison light bulb.

The light bulb ushered in the era of abundant illumination. The mere flick of a switch could now fill a room with bright light. Also, the dangers of open fire were reduced as were the strains of constant maintenance and observation. The light power of electric light was much greater than anything that had been before. The transformation that the new light solution caused for the concept of the interior space also affected architecture and city planning. Now completely windowless spaces were conceivable and an entire infrastructure had to be constructed for powering up buildings. The placement of lamps wasn't dependent on the orientation of the fixture or the reachability to the actual lamp anymore.

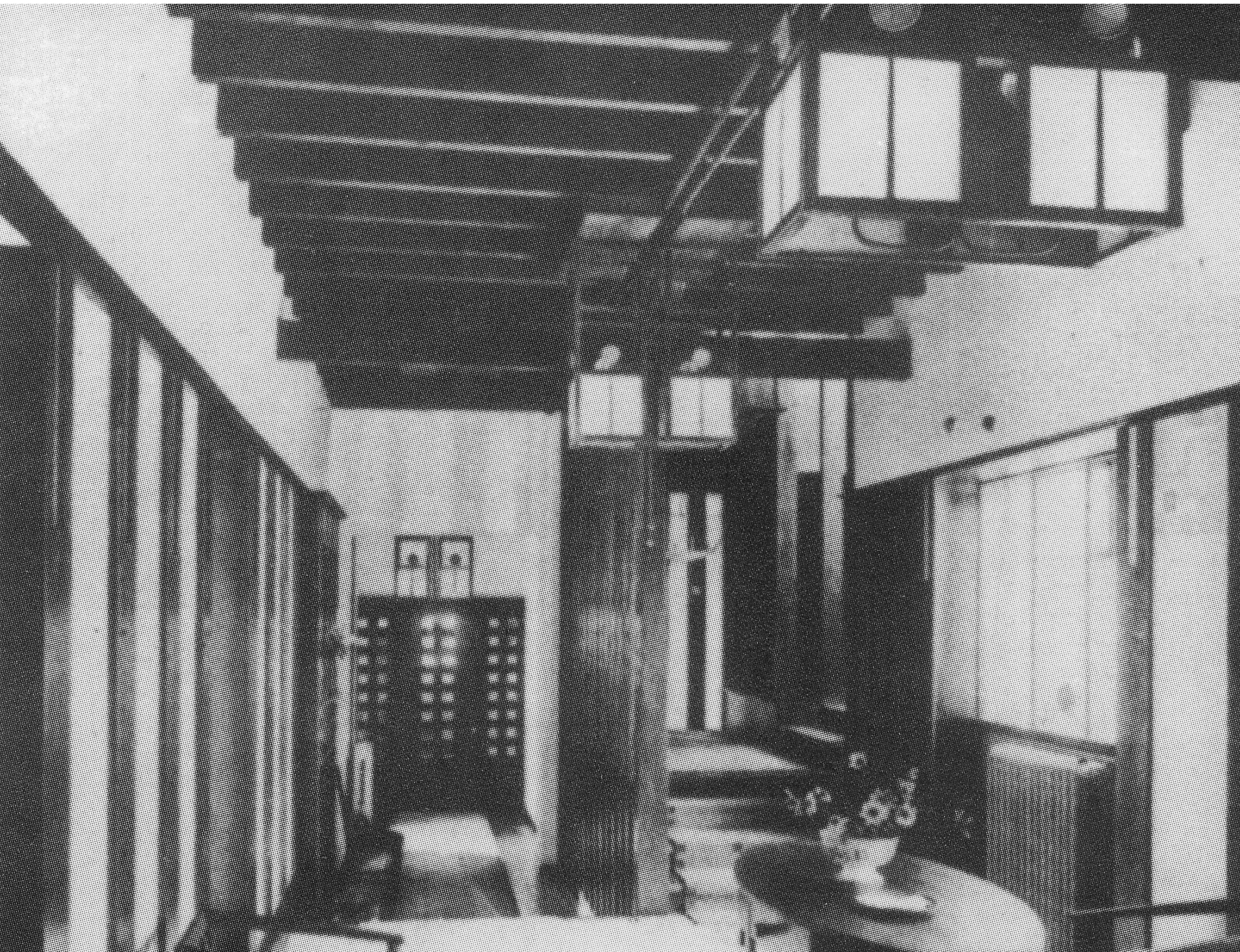
The most typical luminaire categories existed already in the era of oil lamps. Ceiling lamps, wall lamps and table-top lamps had already been manufactured before they were electrified, but new categories were also soon born. The standard balanced-arm work light wasn't possible to produce until a light source that was free of orientational constraints was born. Many stage and specific-purpose professional lights were invented as were illuminative solutions for transportation. The first dry-cell batteries appeared on the market in the end of the 19th century and soon after the commercialization of tungsten-filament light bulbs, torches, or flashlights, became available.

It is noticeable that even though Edison's grand breakthrough in 1881 at the international electricity exhibition in Paris and the following commercial competition with the Englishman Joseph Wilson Swan, also an inventor of the light bulb, began in the late 19th century, the electric light bulb took several decades to surpass the popularity of gas light in Europe. The price of electrifying one's household was a high barrier to overcome for most people and gas lamps had been refined to a tolerable quality. Electrification of major European cities only neared completion in the years between 1923 and 1927 during the post-WWI economic revival (Koch 1994, p.20). In the United States however, Edison himself had set to promoting the building of electricity infrastructures and had shifted his capital from the lamp business to the power business. He saw already at an early stage that light bulbs weren't going to become popular unless electricity was widely available. Businessman to the core, Edison held a strong belief in his campaign and due to his endeavours, in 1892 already seven million light bulbs were manufactured in the booming industry (Fiell et al. 2006).

Lights Design in the Early Half of the 20th Century

As is the case with any field within design, art or architecture, the most significant historical influences from last century are industrialization, modernism and the Second World War. Decorative craftsmanship-based revival styles of the previous century were replaced by decorative and craftmanship-based Art-Nouveau, followed by eclectic fashions later collectively labeled Art Deco, paralleled by functionalism. Like many objects and pieces of interior furniture in the first decade of the 20th century, luminaires still had biomorphic themes and avoided abstract expression. Even most of 1920's and 30's Art Deco still carried a heavy tradition of craftsmanship that confined the task of the designer into little more than adorning an object. Industrial design as a recognized profession was only being born and lights remained relatively traditional in style.

Figure 4 - Japonism in action: 1903 Hill House hall interior by Charles Rennie Mackintosh, featuring quadrangular lights.



In the history of lights design, the early modernist designers were often architects. The early signs of a simplified form language in lights design came from prominent architects. As was the case with Bauhaus, geometric primitives were to set a starting point for the development of modern expression in architectural form language. Seeking possibilities to adapt their luminaires to the cubic character of their buildings, architects looked for inspiration in quadrangular lanterns that were popularized during a fashion boom in the late 19th century known as 'japonism'. As geometry was the principle of form for architects, Charles Rennie Mackintosh, Josef Hoffmann, brothers Greene and Frank Lloyd Wright made the quadrangular light a prominent element in their interiors.

The main content of modernism in design is functionalism. The functionalists sought plain and constructive solutions to camouflaging the novel phenomenon of electric light. One of the most influential lights designers of the pre-WWII era, and indeed post-WWII, was Danish industrial designer Poul Henningsen. His lamp shades in the famous PH-series that featured one or more curved round surfaces aimed to indirectly hide the bulb without hindering the light, and achieved accolade at the 1925 *International Exhibition of Modern Decorative and Industrial Arts* in Paris.

Meanwhile in Weimar, under the guidance of Walter Gropius, Bauhaus was adopting the 'mechano-aesthetic' that allowed modern production materials and geometric shapes to determine the appearance of products. The rejection of decoration in favor of the new industrial age and a belief in the simple beauty of reduced geometrics was the key task taken on by Bauhaus in the 20's. However ordinary and unprovocating Bauhaus products may seem to the 21st century person, they weren't always easily accepted by their audience. For instance, the iconic Bauhaus Lamp (Figure 5) by Wilhelm Wagenfeld was met with ridicule and criticism at the Leipziger Herbstmesse in 1924 (Droste 1990, p.80). It is easily forgotten that what we today take for granted or even perceive as old-fashioned has only a couple of generations ago been revolutionary and visionary.

During the time when the incandescent light bulb was being perfected, lighting technology emerged as an independent field of study and science. Outdoor lighting and interior illumination began to be seen as a problem that could be addressed with scientific methodology. This was an indirect repercussion of controllable and measurable technology entering the field of lighting in the form of electric lamps. Lighting engineers of the 20's studied the requirements of light in different conditions and methods to meet these needs. The paraboloid reflector was invented as a result of calculations that aimed to bring a spot of concentrated light to a certain location.

Figure 5 - Model No. ME1, or The Bauhaus Lamp, by Wilhelm Wagenfeld (1924).

Later these reflectors were adopted for use in cars, bicycles, desk lights and other places where a light was required to be cast in a desired direction. In 1932, British automotive engineer George Carwardine invented one of the most influential and widely-copied luminaires of his century; the Anglepoise balanced-arm lamp (Figure 6). It was inspired by human anatomy and vehicular suspension. In a limited space, it allowed free orientation and positioning of the light with exceptional ease and quickly became a commercial success.

Figure 6 - Model 1208 Anglepoise task light by George Carwardine (c.1933).

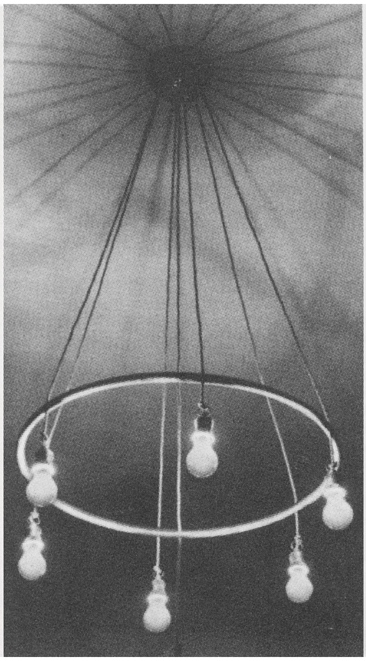


Figure 7 - Chandelier by Adolf Loos (1900).

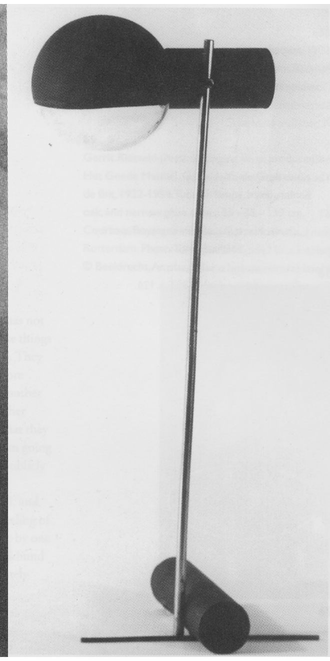


Figure 8 - Table lamp by Gerrit Rietveld (1925)

During the early 20th century, several important discoveries were made that would later be manifested in popular lighting solutions. The forerunner to fluorescent lamps, the mercury vapor lamp was patented in 1901 by American Peter Cooper Hewitt. In this arc lamp, mercury vapor was enclosed in a glass bulb (Bellis 2003). Only twelve years after the discovery of neon gas, the French engineer Georges Claude publicly displayed the first neon lamp in 1910 in Paris. In the 1920's, neon gas signs became a popular outdoor fixture (Bellis 2001). The fluorescent lamp was first patented in 1927 by Friedrich Meyer, Hans Spanner, and Edmund Germe but it wasn't widely commercialized until after WWII. The difference to mercury vapor lamps was that fluorescent bulbs were coated on the inside to increase efficiency.

It was in engineering that the aim to produce light fixtures suitable for serial production began, but in the era of functionalism this was soon followed by architects. Both glass blowing in moulds and the spinning or turning of copper gave rise to 'sphere-, cylinder-, or cone-related forms' (Koch 1994, p.53). The opalescent round glass ornaments suspended from metal tubes were a natural result of a geometrizing of shapes that wasn't only about a preference for Platonic purity but also a logical consequence of available production techniques. Marianne Brandt from Bauhaus, Adolf Meyer from the Zeiss-Ikon-Werke in Berlin and Dutch designer Willem Gispen are examples of early designers who followed the guidelines given by Bauhaus-educated artist Werner Gräff who recommended that architects should look for inspiration in existing products, then improve them in unpretentiousness, clarity and good proportion (Koch 1994, p.51). The aim was to bridge the gap between an engineer's and a designer's insight. Due to the crafts tradition, architects and designers often had a relative ignorance of mechanized methods.

Uncompromising Austrian architect Adlof Loos attempted to achieve dramatic simplification of lights and already in 1900 designed a chandelier composed only of six light bulbs with their power chords and a hoop of copper tubing (Figure 7). Dutch furniture maker and architect Gerrit Rietved also had a taste for minimalism

Figure 9 - Taccia table light (1962) by Achille and Giacomo Castiglioni.

in 1922 when he designed a hanging luminaire that consisted of an oak square and three hanging tubular lamps. Especially Rietveld had a fascination for the source of light itself and attempted to harness the bulb to serve as the shade and the aesthetic centerpoint. In his table light from 1925, he painted half of the bulb to function as a shade (Figure 8).

After WWII, minimalism experienced a revival, namely in the work of Italian designers Gino Sarfatti and the brothers Pier Giacomo and Achille Castiglioni. Only after 1945 did the styles in interiors that we today recognize as modern become truly popular. It took the modern age decades to shake off the ornamental traditions of the past and during the latter half of the 20th century, the most influential factors that affected lights design were advancements in technology. The incandescent bulb had enabled the production of almost any kind of luminaire and the spirit of free creativity had caught on. Furthermore, the devastation of cultural heritage as well as material wealth discouraged the excessive use of decoration and called for a new mindset for producing goods.

Lights Design After WWII

After the war, metals and glass weren't suddenly as available in Europe as they had been before. Economies had a lot of getting on their feet to do, but the seed for change in design practice that had been planted in the twenties started to sprout in fertile burned ground. Courses leading to a design degree were established in many countries during the fifties, which was to heavily affect industries a decade or two later. Inspiration to design education was sought from the best models of American and German education. The overarching theme was the collaboration between art and industry, as pioneered by Bauhaus. New methods and materials were emerging. Plastics, marketing and ergonomics were soon made known to designers. Eventually pop culture and countermovements to functionalism shaped the design landscape and once more attempted to distance the contemporary age from the past, away from tradition.

The 1940's saw the emergence of New Look that consisted of designers creating lighting products strongly influenced by new materials developed during the war and drawing ideas and expression from the contemporary art world. Italian designers, such as Gino Sarfatti, led the new direction that was based on the concept of industrial sculpture. Imagination and low-tech manufacturing met in his visions that explored the emotional potential of artificial light (Fiell et al. 2006, p.30). Italian companies dominated the lighting industry during the first post-war decades with innovative concepts and a will to push the boundaries of aesthetics.

For the first half of the century, most designers had happily used filament-based light bulbs, but during the 60's and the 70's when halogen, fluorescent and neon lamps were available, designers started truly experimenting. In the end of the century human factors and ergonomics started to get more attention. A functionalist-like approach re-emerged in the study of workplace comfort and mood.

Fluorescent Lamps

One of the very first fluorescent light systems, Lytespan, appeared on the market in the 1940's and was manufactured by the American company Lightolier. The product was already in 1948 strikingly similar to the fluorescent rectangles that pattern today's office ceilings. Soon thereafter the fluorescent tubes entered the offices and schools of Europe. Their success was unstoppable and overwhelming as a belief in the advantages of this miraculous innovation that saved electricity and provided a daylight-like colour of light was strong. Eventually the bluish light and poor colour rendering that hindered domestic application of fluorescent light were improved and designers set to creating fluorescent lights for the home. Gino Sarfatti created a ravishingly simple vertical floor lamp in 1954 for his company Arteluce (Figure 10).

For widening the possible usages of fluorescent lamps, different shapes and sizes were produced from the fifties on. This made the creation of desk lights and table lights possible and in 1957 Swedish design agency A&E made the Lucifer desk lamp with two fluorescent tubes. The adoption of fluorescent lamps into the home has never

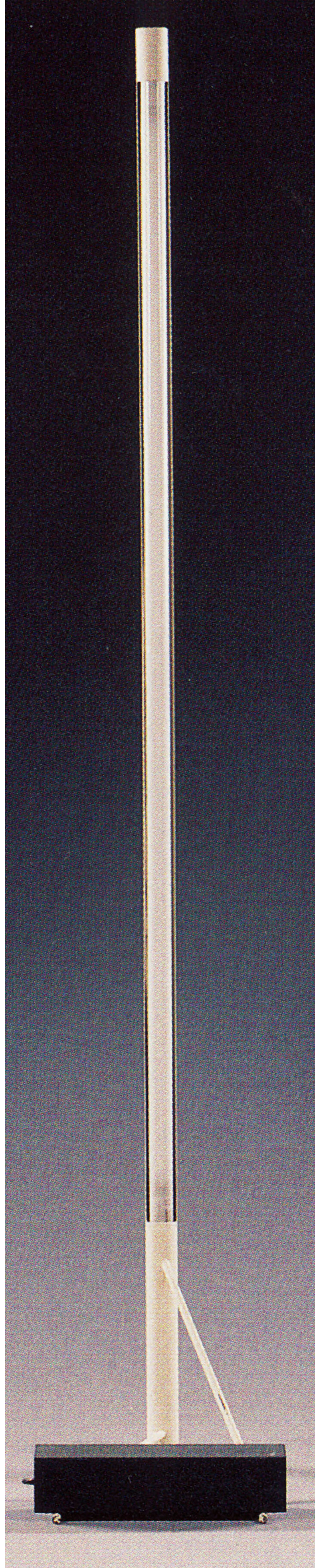


Figure 10 - Model No. 1063 floor light by Gino Sarfatti (1953-54).

truly happened because it is perceived as cold and unnatural light. It also makes a silent humming noise that the incandescent bulb doesn't. Only after the turn of the millennium when compact fluorescent bulbs have become cheaper and more popular and the incandescent bulb has been partially banned in some countries, the gas-filled tube has made its way to our homes. Today, there is growing concern about the environmentally hazardous materials that fluorescent tubes contain as product life cycles are recognized by the public. Another energy-saving option to replace the old bulbs with is the LED bulb that doesn't contain poisonous substances.

Halogen Lamps

Halogen light is often marketed as an energy-efficient alternative, but this isn't quite the case. Halogen lamps also produce a vast amount of heat compared to light emissions and only do a little better than incandescent lamps in terms of energy-efficiency. Before the 70's, halogen lights were only used in technical equipment, like spotlights, aircrafts and cars. Experiments in the 60's had shown ways to employ the halogen light in domestic environments as well, the most notable example being the innovative 1962 floor lamp Toio by brothers Achille and Pier Giacomo Castiglioni (Figure 13).

Halogen lamps were considerably smaller than regular light bulbs. This prompted designers to create lights that made the most of the small size of the light source. A notable feature in 70's and 80's halogen lamp design is the tendency of the tubes and shafts that support the light to be as thin as possible. This happened because it was

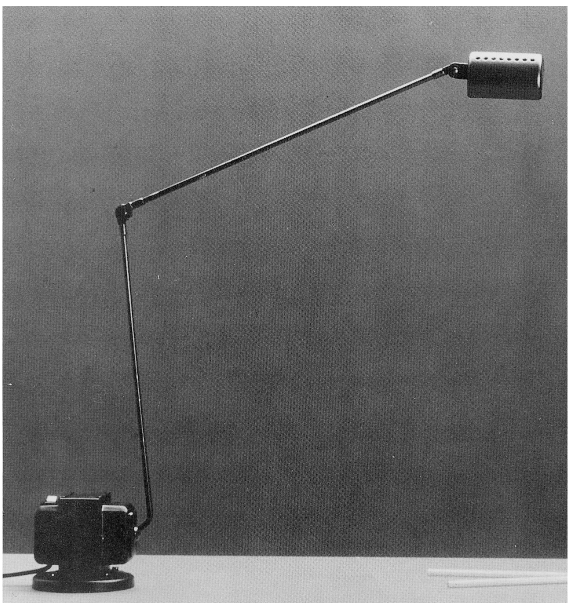


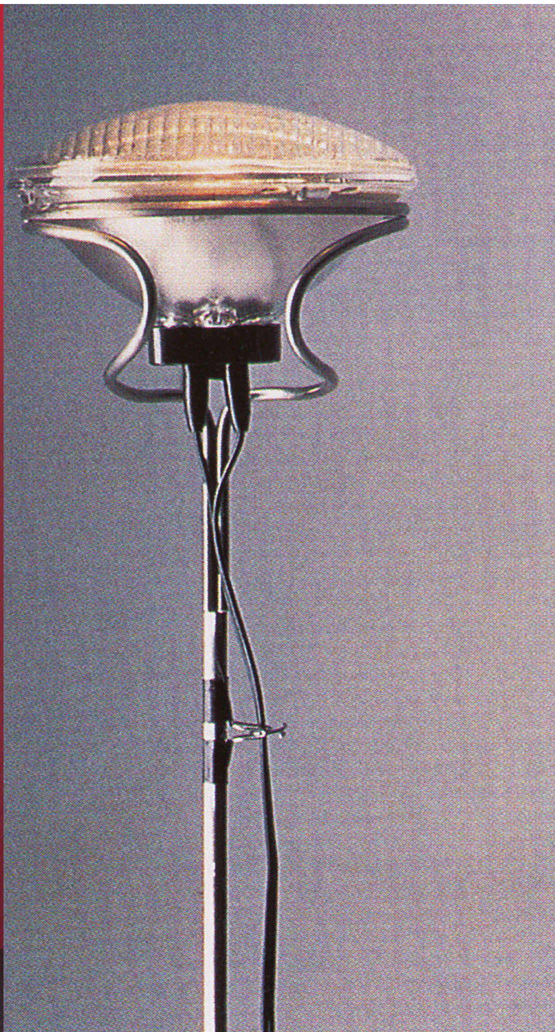
Figure 11 - Daphine by Tommaso Cimini (1976).

possible and designers fearlessly exploited the chance they had, like Tommaso Cimini did in 1976 when he designed the Daphine desk lamp (Figure 11). Using low-voltage lamps made it possible to carry electrical current on the exposed frame of the luminaire, but meant that there had to be a transformer. In 1972, Richard Sapper articulated both features in his counterweight-balancing desk light classic Tizio (Figure 12). This design concealed the transformer and used it as a weight in the base of the luminaire. It won awards and became somewhat of an 80's yuppie icon due to its sleek and formal, yet creative design.

Some decades after their introduction, it is safe to say that halogen lights didn't replace the incandescent bulb either. They are mainly used where a spot of light is required and as such are best suited for illuminating paintings on walls, products in department stores or desktops in office settings. While halogen technology didn't quite create a revolution in lighting design, it certainly allowed for new forms and expressions in

Figure 12 - Tizio table lamp by Richard Sapper (1972).

Figure 13 - Toio (detail) from 1962 by the brothers Castiglioni.



the design of luminaires. A halogen lamp can typically be recognized for its features even without seeing the light source itself. They are thin and as small as they can be and often made of metal to further accent the sleekness and high-tech appeal that the technology allows. The halogen industry also provided the world with some other technological advancements. Power transformers for instance had to be developed and made smaller. The minute bright point of light that is the center of the halogen light source required new kinds of reflectors. The faceted mirror reflector as well as modernized dimmer switches both followed in the wake of the halogen lamp.

Lights Design in the 21st Century

Technology has throughout time been the main factor and inspiration for lights designers and the 21st century looks to provide designers with even more freedom of choice than before. There are signs that compact fluorescent lamps are going to fade away in the coming years as LED lamps will become more affordable, but nothing indicates that fluorescent tubes would be on their way out. For example, Philips has ceased research on compact fluorescents, choosing to focus on solid-state lighting instead (Taub 2008). One interesting sidetracking trend in lights design has been a long goodbye to the beloved and symbolic incandescent bulb. In this retro- and introspective designer's lamentation, the light bulb is the star of the show. Lamp shades may be made in the shape of a giant bulb like in the case of Japanese studio Kyouei (Figure 14) or Suck UK (Figure 15). Many shops market large low-power clear-glass bulbs that celebrate the visible filament that glows bright orange. This is a passing

Figure 14 - Bulb Lantern from Kyouei Design by Kouichi Okamoto (2008).

Figure 15 - Wooden Bulb from Suck UK by Barend Massow Hemmes.

emotional trend that is a natural manifestation of the consciousness that the public has about the old light bulb lying on its death bed.

LEDs

Since high-brightness white LEDs were developed to a decent level of quality around the turn of the millennium, light-emitting diodes have been the focus of much hope and hype in the world of lights design and consumption. LEDs' lifespans are tens of times longer than those of the typical incandescent bulbs, they consume only a fraction of the energy, they produce little heat, they are highly reliable and they operate at safe voltages (Morris 2006). Downsides of LEDs are mediocre color rendering and glare. Much like halogen bulbs, LEDs are bright little points that aren't comfortable to look at. Even lower-powered larger batches of LEDs are not appealing in appearance and call for a diffuser. The main cause for complaints from consumers has been the price. LED bulbs to replace a typical 60W incandescent bulb aren't widely available and slightly lower powered ones have only very recently become available to regular customers. A seven-watt LED bulb to replace a 40W incandescent one costs about twenty times as much as the typical 1€ incandescent bulb. The LED bulb falls short in appearance and from a designer's perspective it would be more recommendable to have different lamps for the different technologies altogether. The LED luminaires that are on the market seem very difficult to replace lamps to. This is understandable because the life expectancy for a heavily used LED lamp might be up to twenty years and it's extremely difficult to foresee what kinds of standards have been developed by that time.

Figure 16 - A typical LED light bulb that imitates the ancient appearance of incandescent light bulbs.

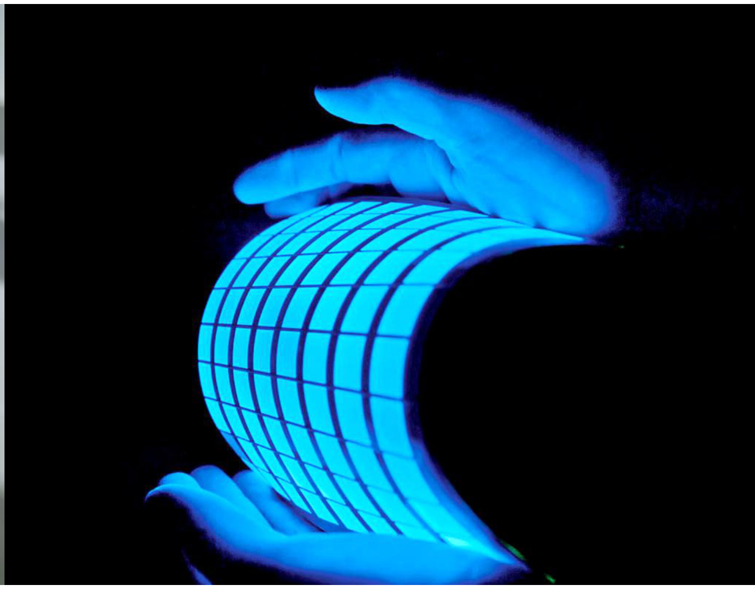
Overall, designing luminaires with LEDs is a design practice that is still taking shape. There aren't any reliable standards that designers can adhere to or even a crystal clear perception of what the main advantages of LEDs are. The truth is that LEDs are still in a rapid phase of development and new levels of luminosity, colour rendering and efficiency are constantly being achieved. LEDs have great potential for overall spatial lighting as well as focused spot lighting. Their small size and low required voltage will give designers greater freedom than the large and hot incandescent bulbs, but it is up to designers to make the most of them. In the same spirit as designers a hundred years ago set to conceal the light source, contemporary designers have to deal with the question of glare reduction when designing LED lights.

WHERE OLED PLACES THE DESIGNER

Although electroluminescence in organic materials had been observed since the 1950's, the first diode device was reported at Eastman Kodak by Ching W. Tang and Steven Van Slyke in 1987 (Tang et al. 1987). Their research led to further discoveries and eventually the era of contemporary OLED production. After years of promise, OLED technology has found its way to many of today's gadgets. In higher-end portable devices OLED is already the default choice of display technology and even large televisions have entered the market this year. Compared to LED displays, OLEDs have greater contrast, better brightness, wider viewing angles, quicker response times and they use less power. They are also much thinner since they don't require a backlight.

Figure 17 - A small OLED light.

Figure 18 - A bendable blue OLED light.

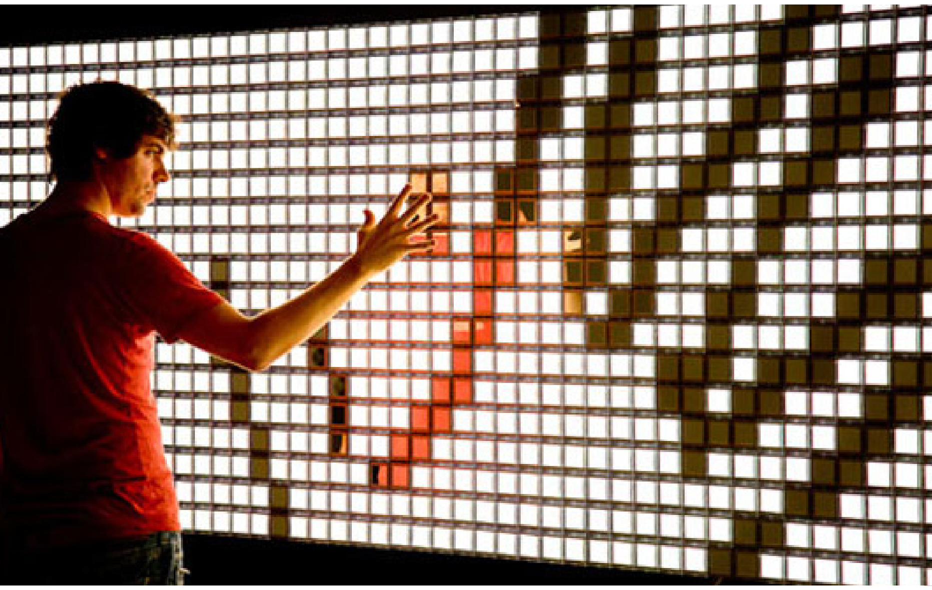


OLED technology has certainly found its place in the world of displays, but it also shows strong promise in lighting. OLED lights have only been produced for a few years now and they have a long way to go until they can be widely adopted. Some of the challenges that OLED lighting is facing today are cost, efficiency and standardisation.

OLEDs are very different from all the previous light technologies that have shaped the practice of design. The most obvious difference is the shape. OLEDs are surfaces that produce diffuse distributions of even and harmonic light by their very nature.
The first ever luminaire to use OLEDs was Early Future, an OSRAM Opto Semiconductors table light designed by German lights design veteran Ingo Maurer. The light was unveiled at the Frankfurt Light+Building fair in 2008 (OSRAM 2008). Only 25 pieces were produced, each priced around 25 000 euro. Since then, other companies have unveiled their products and prices have come down significantly. In all of the OLED luminaires that are available, the design closely follows and displays the shape and size of whichever OLED component has been used. Many of the luminaires have only been designed to promote an OLED manufacturer, the most important ones in the business today being Philips, OSRAM, Lumiotec, LG and General Electric. The business isn't yet profitable because of the high cost of production but the investments from these large corporations are optimistic. Some companies, like Philips, sell small OLED kits that hobbyists and professionals can use to study OLED lighting.

Figure 19 - Philips Lumiblade Reflections installation (2010).

Figure 20 - Ingo Maurer's Early Future (2008), the world's first OLED lamp.

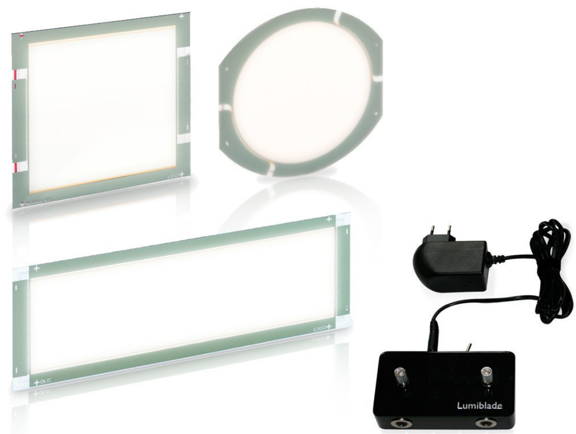


Up to a certain brightness, OLEDs require no diffusers because the task of a diffuser is to distribute light evenly and harmoniously. As OLEDs also are very thin, they can be fitted into places where illumination has been unattainable before. OLEDs can be made transparent, which enables the integration of lights into windows and other see-through objects.

Even transparent and flexible OLED displays have already been manufactured and there's no reason why that wouldn't apply to OLED lamps as well. Because the light source emits very little heat, bendability adds a whole new dimension of potential usabilities to the material. It means that lamps can be shaped into difficult forms both in rigid and flexible ways. The OLED industry is promising great energy efficiences in the future as well as long lifespans for OLED lamps. The true effects of the new technology on lights design and interior architecture will take a decade or two to manifest, but already now it is certain that the potential uses of artificial light have once more been expanded vastly.

Figure 21 - OSRAM PirOLED (2010)

Figure 22 - The Philips Lumiblade Plus 2 Experience Kit is sold for 172€.



OLED is an exciting new technology and it has inspired many others to explore its design possibilities. Thinness and being able to bend have been sources of inspiration for many concept designs. In 2010, the wall lamp Light.Form by Francesca Rogers in cooperation with Daniele Gualeni Design Studio for ILIDE – Italian Light Design was displayed at Milan Design Week (Figure 24). Physical interaction is combined here with the smoothness of OLED light. A very recent bendable OLED design comes from Hungarian industrial designer Gergő Kassai. This bendable 2012 concept is called Motion Lamp (Figure 25) and dreams up beautiful uses for the emerging lighting technology.

Commercial OLED lighting products sometimes make use of expensive high-performance materials. The 2011 OLED luminaire Victory by Liternity (Figure 23) is made of carbon fiber and fitted with four OLED panels. In 2010, Serbian design studio D Signed collaborated with the Fraunhofer Institute to create Lamped, the OLED floor light that can be bent according to user needs (Figure 26). The OLED panels were joined by ball joints.

Figure 23 - Victory by Liternity (2011).

The designer's role, in a situation where a certain technology provides a turning point for a tradition as long as interior illumination, is to envision and

Figure 24 - Gualeni Design: Light.Form (2010)

Figure 25 - Gergő Kassai's Motion Lamp from 2012.

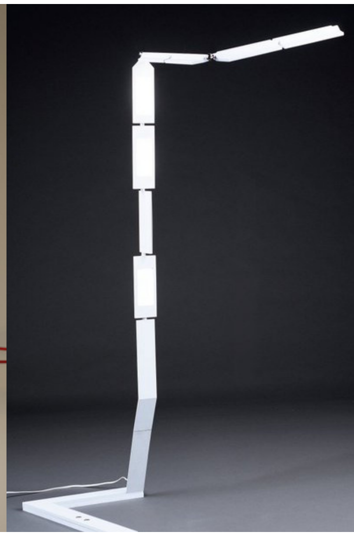


Figure 26 - Lamped by D Signed (2010).

to design uses for that technology. In the best case, designers will collaborate with other disciplines to push the technology to new achievements. In my thesis, I didn't have the joy of collaborating on a light design with engineers, but had I used actual OLED materials, that would have been a necessity. An OLED light source has all the attributes that call for user interaction and interface design. With its lightness, coolness and flexibility, it is a playing ground for industrial design. Design, while not a scientific method, is a method of research. Not all design should aim to produce products. Making prototypes and testing new ideas in practice is vital for developing an understanding of a new subject. It is with this idea that I have created Idleply. The aim has been to first refine my own understanding about the potentials of OLED lighting, then to try my ideas in practice and finally to communicate what I've learned to others.

FUTURE PREDICTIONS FOR THE OLED INDUSTRY

OLEDs still have a long way to go to become a mainstream product. Advances in production technology and massive financial investments in the industry speak of a strong and widespread confidence in their becoming one of the standard light sources of the near future.

Market Research Predictions

The market research company Nanomarkets regularly conducts analyses of the current state and future prospects of the OLED industry. According to their most recent market forecast of Q2 2012(OLED-Info 2012a), the price of lighting panels will sharply drop within the next two years as major manufacturers will begin mass production. At first that will have a negative effect on revenue, but eventually the profitability will increase as OLED penetrates into the mainstream of lighting. The expected market for OLED luminaires is $6,3 billion in 2017 compared to $0,6 billion of 2010. Even a tenfold expansion in the business won't mean that OLEDs are everyday household mainstream by 2017. That development will take longer but perhaps by 2017, specialty luminaires called OLED are widely known and available to those who are interested.

Nanomarkets predicts that in 2017, over 75% of the revenues will come from commercial and industrial building applications. Mainly they see OLED as an energy-efficient, lower-cost, improved-aesthetics competitor to standard fluorescent lights. In a related article, Nanomarkets laments the lack of industry leadership (Nanomarkets 2012) and the difficulties that the development of less costly mass production lines is facing. In this article, Nanomarkets expects it to take 3-4 years for a real OLED lighting market to emerge. The economic slowing down of Europe is slowing down the development of OLED technology as the industry has so far been very Europe-centered. The construction of new buildings in developed countries has also slowed down and the deliberate phasing-out of incandescent light bulbs is advancing with uncertainty. However, there are reasons for optimism. According to the article, the

OLED industry is moving into a less flashy stage of building up mass production and straightening out the kinks and technological issues none of which are insurmountable. In other words, news about OLEDs will be boring for a couple of years but significant development will be happening all the same.

Corporate Roadmaps

Some companies have published roadmaps for their future in the OLED market. For instance, the manufacturer of Lumiblade OLED lamps, Philips, released theirs in February of 2012 (Philips 2012). Philips has divided its product development into two different areas of targeting: decorative and performance lighting. In the decorative line, they see transparent OLEDs as well as impressive flexible $1m^2$-sized lighting panels in 2018. Less flashy, but perhaps more interesting, the performance line aims at efficacies of 60 lm/W in 2013, above 90 lm/W in 2015 and a whopping 130 lm/W in 2018. Unlike many other companies, Philips also talks about the actual lumen output of their products, which is said to increase from 10 000 lm/m^2 to 15 000 lm/m^2 between 2012 and 2015. At 15 000 lm/m^2, a panel of 24*24 cm would have an equivalent light output to that of a 60W incandescent light bulb. The sizes, intensities and lifetimes of their performance panels are also expected to increase with every step. In February 2012, LG Chem announced that they had started mass production of their "Type 1" panel that features CRI>80, efficacy of 45 lm/W and 10 000 hours of lifetime. It isn't likely that LG Chem is yet using a very cost-effective manufacturing method as this would certainly be reflected in the amount and pricing of the panels that they sell.

	Efficacy (lm/W)	
Future OLED (?)	130-150	(Philips OLED roadmap for 2018: 130 lm/W, U.S. Department of Energy goal for 2015: 150 lm/W)
High pressure sodium	70-150	
Laboratory OLED	102	(Universal Display Corporation 2008)
Commercial LED	80-100	
Fluorescent	50-100	
Commercial OLED	45	(Konica-Minolta & Philips: Lumiblade Plus 2011, LG Chem: Type 1, 2012)
Halogen	15-25	
Incandescent	10-18	

Table 1 - A comparison of luminous efficacies shows differences between popular lighting solutions.

Energy Efficiency and Other Challenges

Energy efficiency is the most important measure of success for new technologies in lighting. It's the determining quality that will eventually decide whether OLEDs are going to make it or not. So far, the most efficient OLED lighting panels that are in production are the Type 1 by LG Chem and Lumiblade Plus by Philips. They have achieved an efficacy of 45 lm/W, which is much better than halogen or incandescent lighting but clearly not as good as fluorescent or LED lighting. In laboratory conditions, the record holder is USA-based Universal Display Corporation that achieved the mark of 102 lm/W already in 2008 (UDC 2008). If this has been beaten by other companies, they haven't made their achievements public. In 2007, the United States Department of Energy marked 150 lm/W as a 2015 goal for commercial OLED light sources (U.S. DOE 2007) although another report of the same department (Navigant Consulting et al. 2007) had earlier projected 100 lm/W as an efficacy that will be commercially available in 2015. In the light of recently published roadmaps, the less optimistic of the two expectations seems more realistic.

A very specific challenge in moving to mass production is moving from layer-to-layer vapor deposition to solution processable materials. Layer-to-layer vapor deposition is slow, expensive and it consumes a lot of energy. It is only suitable for the production of costly high-end displays and small volumes of expensive lamps that are available today. A great deal of effort is being focused on the development of solution processable OLED materials that would allow the manufacturing of displays and lamps via inkjet printing and spin coating. Printing the materials directly on a substrate would make the production of OLEDs significantly more affordable, quick and energy-efficient. To a great extent, the OLED revolution of the lighting market depends on overcoming this challenge.

One of the future obstacles that OLED lighting has to overcome is standardization. That challenge luckily has little to do with technological difficulties. With the current absence of a clear market leader or large-scale mass production, any attempt at a standardized OLED connectivity would be ahead of its time. It is still unclear what will be the most prominent uses for OLED lights, or what will be their most practical size. Before the industry has gained that knowledge, standards can't be implemented, as they might become unsuitable after a while.

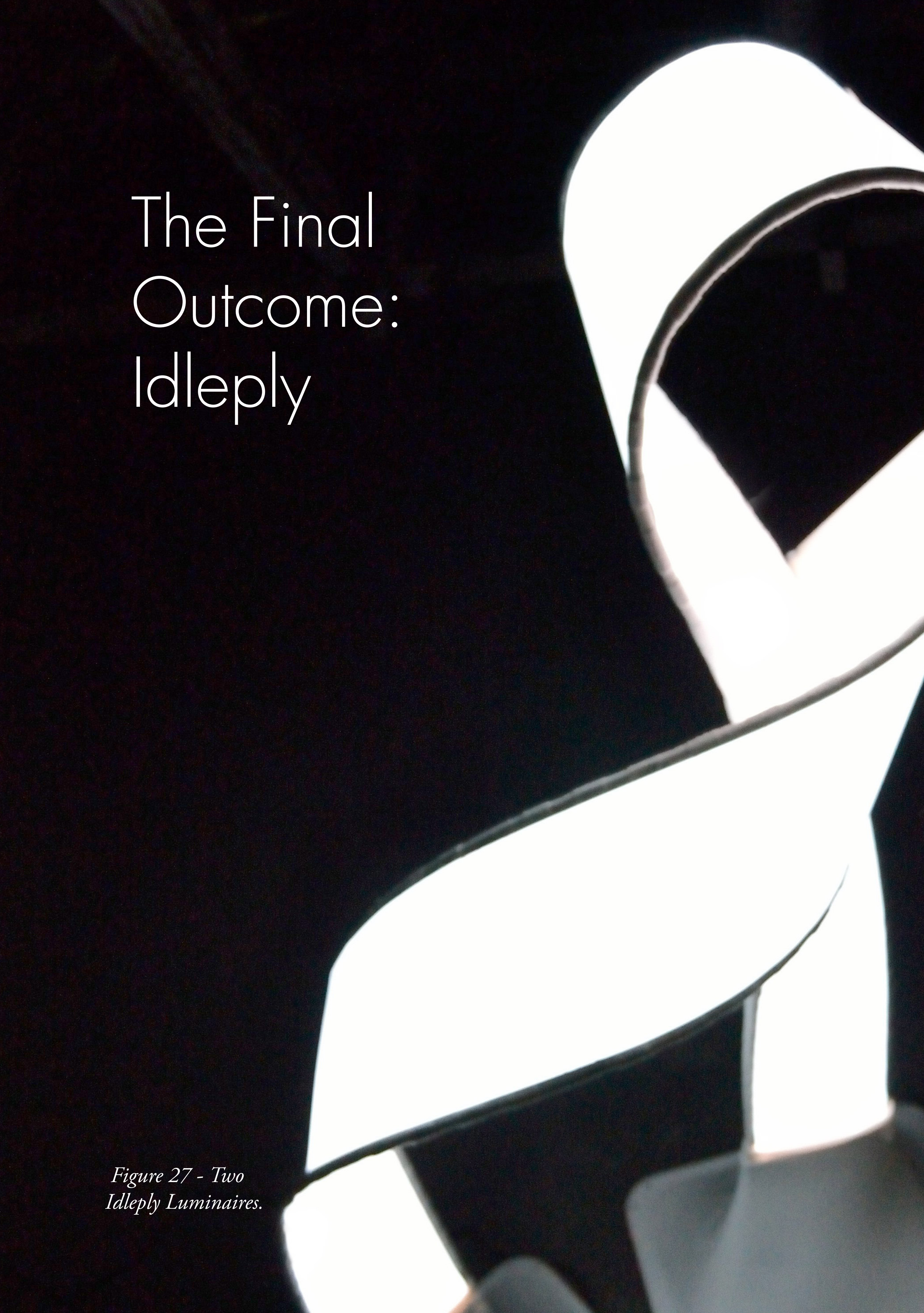


Figure 27 - Two Idleply Luminaires.

DESCRIPTION OF THE FINAL PRODUCT

Idleply luminaires are tall and flat floor lights with multiple uses. The 183-centimetre lights can be bent to fit more specific lighting purposes than just smooth ambient light. They can be shaped to function as reading lights or desk lamps and they give the user a fun artistic freedom in exploring different form possibilities.

The Idleply luminaires are a concept design for OLED technology. They are a research into what lights design may become in the near future. Although actual OLED sheet isn't yet available for projects such as Idleply, the prototypes demonstrate what could be achieved in the next decade. The luminaires make use of electroluminescent sheet which is much less bright than OLED, but similar in other respects. Both are flat sources of diffuse light and both can be flexible.

Figure 28 - The light sources are of different lengths on the two sides.

Figure 29 - Idleply luminaires with both sides switched on.

An Idleply luminaire features two switches on its foot. Placed side by side, the longer one switches on the full-length side and the shorter switch operates the half-length side. By switching both switches up, the luminaire will shine light on both sides. The lamp can be touched, turned and twisted while it is on, as the EL-light source only gets mildly warm and is well isolated. This would be the case with OLED light sources, too. The light is connected to an electric inverter via a long thin wire which allows it to be moved around on a large area.

The foot of the luminaire features rubber pads on the wooden sole and a plastic casing to cover up rugged structures as well as wires. The long spine is covered in fabric and EL-sheet with a plastic head bit that can be used as a handle when manipulating the lamp's shape. The overall style of Idleply is a simplified look that creates little contrast to any contemporary interior. The technological and futuristic starting point of the project is not a theme in its styling, but rather style that has been avoided. Instead of attempting to forecast future design trends, Idleply has a hint of 60's plastic design. The long spine is covered with a soft textile because the luminaires are objects to be touched,

Because the light source is a wide sheet, the light is soft and requires no shades or diffusers. This direct light resembles indirect light in that it causes no glare, which makes it ideal for indoor lighting. Especially in limited interior spaces and in work lights, OLEDs have tremendous potential. The Idleply project includes a prediction that in the next ten or twenty years, lights like these will become increasingly popular in many different interior spaces.

Figure 30 - The head.

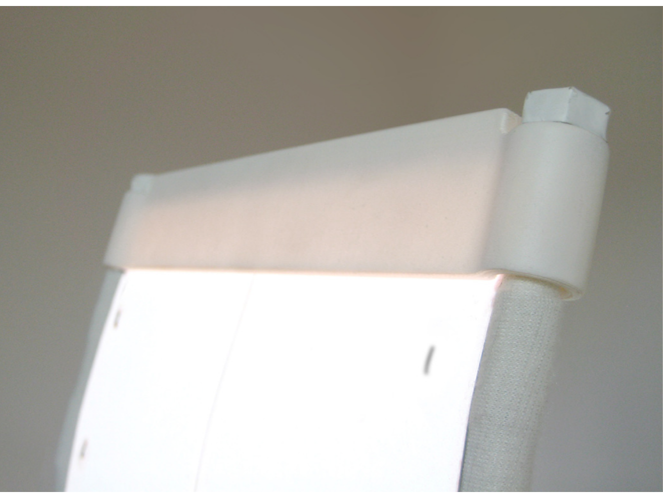


Figure 31 - Detail of the foot.

Figure 32 - Lights facing the wall.

CONCEPT DEVELOPMENT

As a designer and a design student, I have always been fascinated by lights and lamps. As objects, luminaires have maintained a sculptural and visual freedom that other things of the interior have had to abandon in favor of functionality. For instance, a ceiling light is rarely touched. It typically gets to occupy a large space on its own, completely unobstructed by any nearby furniture. It is the most visible thing in the room – its task is to render everything else visible. Lamps are often things of beauty and form. The fascinating interplay of shading and revealing the light source is traditionally an essential part of lights design. It is in designing luminaires where designers may let their creativity run free without ever compromising usability by flamboyantly overstating needless features. It is because lamps are only useful when you're not gazing at them, that they can host exceptionally appealing visual qualities. You don't hold and manipulate a ceiling light when you're using it. In the functional spectrum, the lamp's only offering is radiation. This makes it more than an object, more sublime than material. A poetic shape is perfectly even with such functionality.

From Lamp Shade to OLED

Initially, my idea was to design a lamp shade concept or a light based on conventional technology as a thesis project. Themes that I was thinking about were bioplastics and modularity, but as I went deeper into the subject of lights design, I realized that only making a light diffuser isn't enough. To truly design a luminaire, one has to design where and how the light is formed. Having gotten to know OLED technology through studying Ingo Maurer's work, I was inspired by the possibility to question the roles of the shade and the light source. With surface light sources, it would be possible to make luminous lamp shades that leave a shadow on the unseen side and lack a bulb entirely. A conviction that can be found in Maurer's work is a belief in the significance of the designer in tracing future trajectories for novel technologies. To study the possibilities of promising technologies from a design perspective will yield different results from those obtained in engineering laboratories. In the best case, those results are complementary and inspirational to each other.

The modern world has good cause for growing concern about the environment. Many measures have to be collectively taken to hinder the global environmental deterioration. Reducing energy consumption is a necessity for the contemporary man and has become a persistent trend even in the consumer market. Any new technology that will help people to save energy is a welcome one. One advancement in illumination technology isn't going to save the world but it can be a step in the right direction. Since I determined to make a lighting concept as a thesis project, it was self-evident that the project was going to have an energy-saving perspective to it. It is the designers' task to advance environmentally conscious values in product development. OLEDs, as well as LEDs and fluorescent lamps, have a tremendous advantage in energy saving compared to incandescent light bulbs.

From a strictly aesthetic point of view, what OLEDs offer in terms of redesigning light fixtures is nothing short of a revolution. All light sources since the dawn of time were point sources until the fluorescent tube was invented and popularized. The fluorescent tube added one dimension to the point by stretching it into a line. This line then could be bent into curves and shapes and even animations, which presented light designers with a world of inspiration. However, even the fluorescent tube had the thickness, the heat, the frailty and the rigidity that were known from the light bulb. Lighting up a surface evenly was still a major challenge and most lights that employ a fluorescent tube still rely on a diffuser or a shade. Although the point was stretched to a line, sufficient light power was still required, which caused glare.

If a point can be stretched to a line, then a line can be stretched to a surface. When the amount of light that emanates from the surface is equivalent to that emanated from the point, the even distribution of brightness over the area of the surface is exponentially reductive of glare. The result is a harmonic, large-area light output.

OLED Ideations

The idea of designing luminaires based on the principle of surface light from a technology that has a lot of promise for the future was inspiring to me. During recent years, LED lights have really made their way into the mainstream. This success didn't come as a complete surprise as development in LED technology had started years earlier and signs of future mainstream popularization had been visible for a long time before. Today, signs of mainstream popularization of OLED lighting in the future are visible. The question isn't if it's going to happen but rather, when is it going to happen? Time and technology will answer that question and meanwhile designers will create designs for future lighting.

Good concept design begins with plentiful ideation. In the ideation process, I aimed to produce many ideas, more than I would be ever able to bring to life. I followed an unplanned path that took me from conventional hanging-light shade-like solutions to the final stages where I was more focused on the strong points of OLEDs and how the different possibilities that they have to offer can be reflected in the development of usability. In a great deal of my ideas, I used 3D modeling to quickly try them out. I used Rhinoceros 3D for making the models and the plug-in V-Ray for making the rendered images. Because it is possible to assign radiant properties to the materials that are rendered, I found this tool very useful for planning surface light sources. I also made a lot of drawings and even some paper models to research how some of the pliable surfaces may bend in real life.

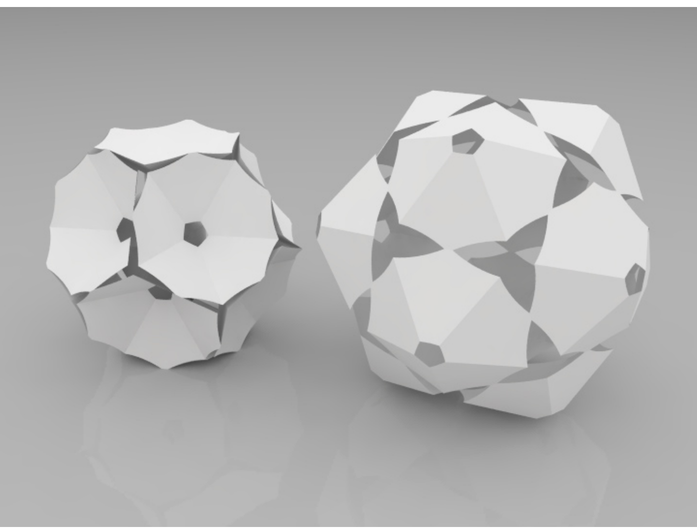
Geometric Shapes

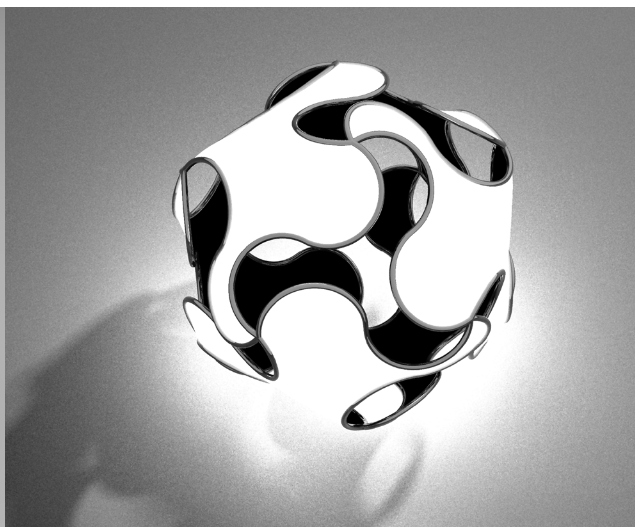
My first approach after adopting the theme of OLED lighting was geometric shape creation. I was thrilled with the unlimited versatility of surfaces and combined that with a keen fascination for three-dimensional geometry. When trying to create a novel three-dimensional geometric shape, it is often easiest to begin with shapes that are based on regular polyhedra. Most typically those shapes are the icosahedron and the dodecahedron. Both are platonic solids and each other's duals. The icosahedron is composed of 20 regular triangles and the dodecahedron is made up of 12 regular pentagons.

My first attempt (Figure 33) to create a modular ball-like hanging or standing OLED design was very much a dodecahedron-like structure. The idea was that each of the 12 panels could be inverted to either be concave or convex.

Figure 33 - A dodecahedron-based shape.

Figure 34 - An icosahedron-based shape

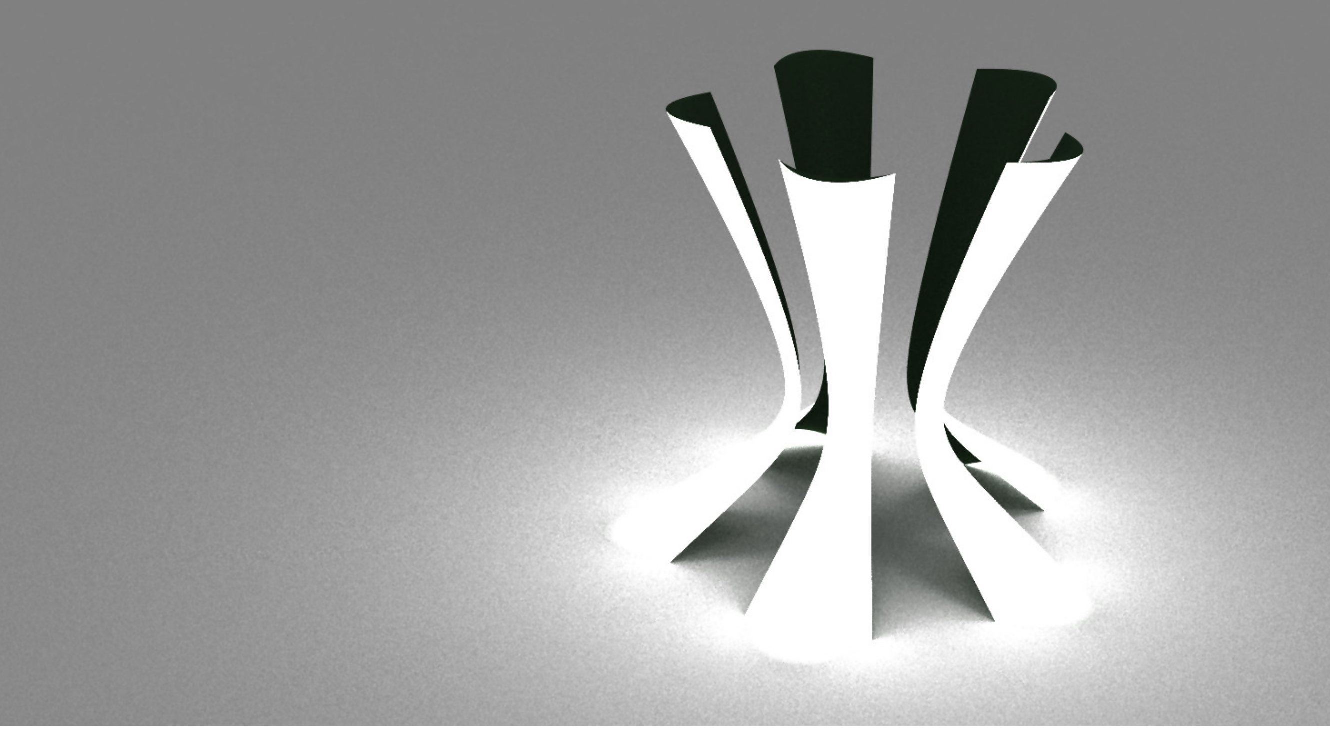




The second design (Figure 34) was a re-use of a geometry I had made sometime earlier for another purpose. This time the underlying map of reference was the icosahedron. The geometric principle can be difficult to distinguish, but the result of a shape like this was that the individual bits could be arranged in many different ways to create slightly different spherical lights. The gaps could either be there or not. One idea was to have the option of using two different shapes that could interlock. This design is very reminiscent of the principles that the Danish design icon IQ-Light by Holger Strøm is based on. The first two ideations are extensions of the idea that in a surface light, the lamp shade can act as the source of the light. For that reason, the designs still look a lot like conventional hanging lamp shades.

I tried out a short floor lamp (Figure 35) that was composed of five circularly arrayed shapes. I was pleased with the aesthetic impression, but on the usability side, the design was one for only a decorative gadget. The reason why floor-level lights aren't popular in spatial illumination is that they are close to useless. Gravity has dictated that most things, including persons, are located on the floor. A light that is also located on the floor is easily masked by opaque barriers and will fail to spray its light effectively around itself.

Figure 35 - A floor lamp.



I then tried out designs of more mass than pure surface, but still based on geometric principles. The first one was a combination of six twirling loops that formed a less shade-like object (Figure 36). The second was an interlock of five outlines of cubes, where half of the corners were light sources and the other half transparent green (Figure 37). These forms were better looking and designed one step further than the previous shapes. The downside was that I had no idea how they would function even on a conceptual and theoretical level.

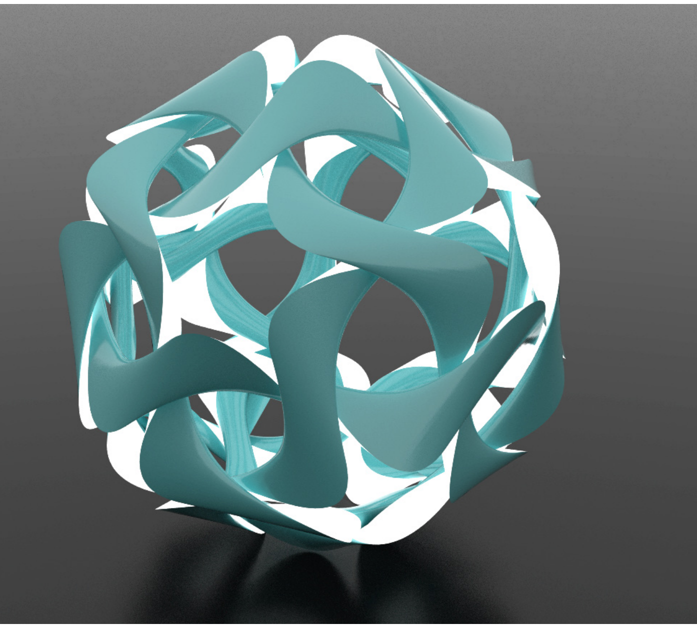


Figure 36 - A combination of six loops.

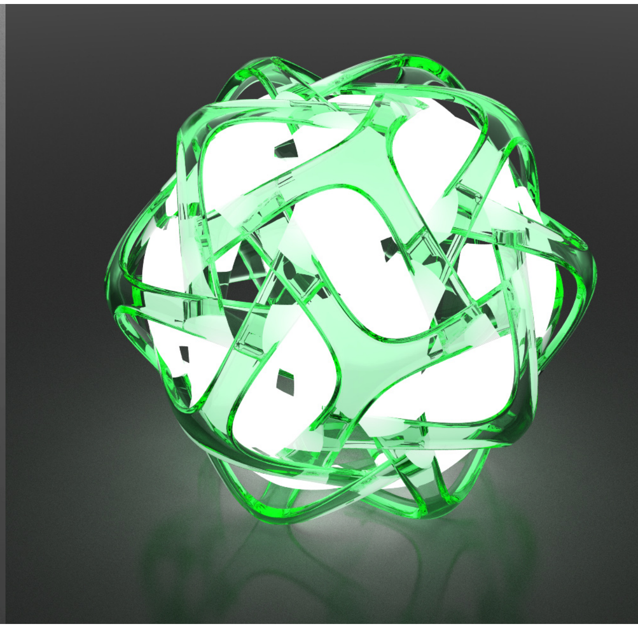


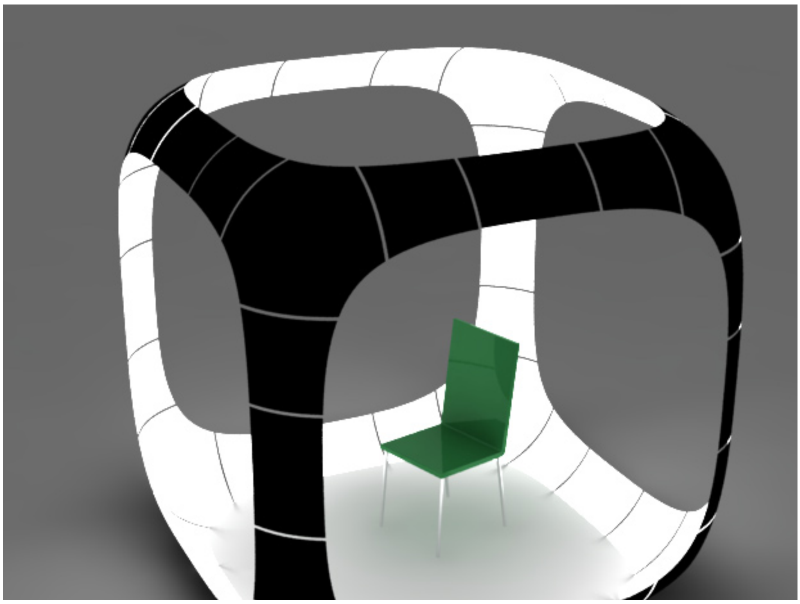
Figure 37 - Five interlocked cubes.

Scaling Up

I decided to scale up, to make it bigger and to look up information about what actual possibilities does OLED have in terms of freeform surfaces. As it turns out, the OLED industry is still struggling to get the basics working well. A bright, energy-efficient hand-sized basic light source is yet to be seen in real OLED mass production. Perhaps one day OLEDs will come in double-curved geometries, but before that, the manufacturers will be clearing the hurdles of basic functionality, reliability, manufacturability, transparency and flexibility. It is always interesting to try to think differently and I haven't found any source implying a double-curved OLED in the future. However, it is difficult to imagine reasons to making double-curved OLEDs other than superficial style. Although my starting point in choosing to make a luminaire as a thesis project was a designer approach that includes an emphasis on style, I didn't want to go too far into the conceptual future and render the project unrelated to the actual near future of lights design.

Scaling up meant planning spatial illumination rather than just lamp objects. I started with the grand and spectacular, within some rational scale. Working with surface light source concepts, I was interested in exploring designs where the light is radiated from multiple sources and large areas. Smooth and comfortable light was to be my goal in a way that would emulate a cloudy day's natural light. I started from an idea of all-round illumination that was the opposite of conventional domestic lighting. In this initial idea of a design, the hanging center-of-the-room light is replaced by illumination from the peripheral areas of a room – the corners and the edges (Figure 38). This is an alternative lighting solution to interiors that I am still interested in trying out in real life. Inverting shady areas with lit areas might actually produce a harmonious result, but might also have unpredictable drawbacks.

Figure 38 - Peripheral lighting.



The second design was inspired by the EL-sheet material that I had come across when I had been looking for materials that I could use to produce prototypes. I sketched the idea in two different scales and couldn't avoid realizing that bigger is always better. This was a very direct execution of material-based ideation and I felt that I could probably find more creative uses for the material. In any case, the design shouldn't be about making the most of what EL-sheet can be used for in prototyping, but about the possibilities that OLEDs can offer. The undulating wide splines were appealing, but I didn't have solid enough arguments to go for that design.

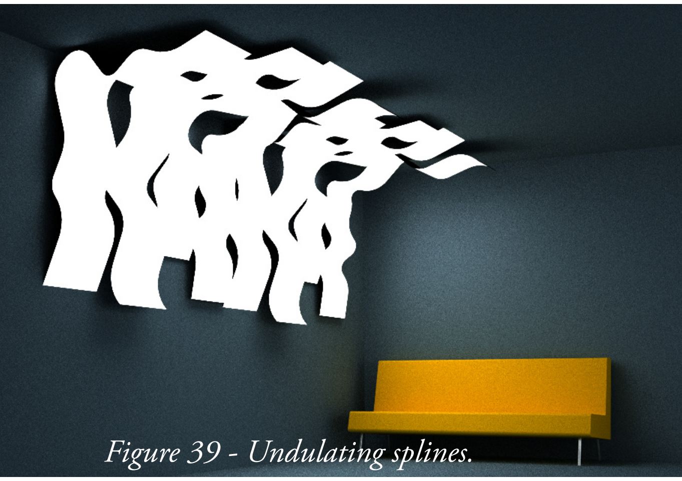


Figure 39 - Undulating splines.

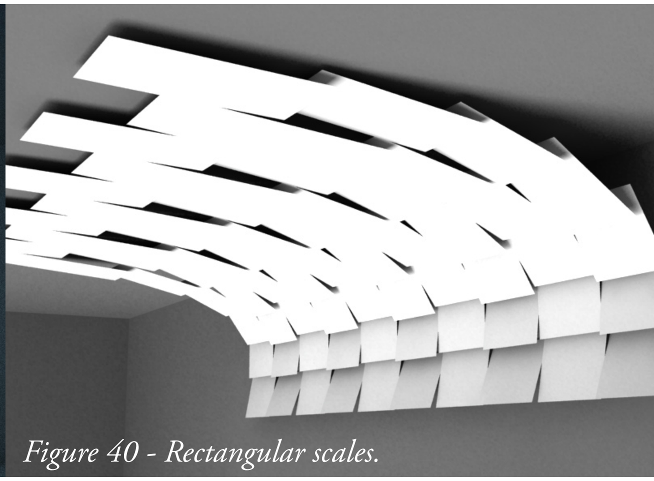


Figure 40 - Rectangular scales.

Another design that I clearly had an idea how to make was a similar set up of rectangular scales in the meeting point of the ceiling and the wall. In full scale, this design too would have produced a spectacular result but I wasn't sure it was the correct use of OLED modules. After all, the individual lights should be bright enough not to require ten square metres of pure light source. I was after practical design that was supposed to reveal advantages of promising future lights. This kind of installation would probably have made more sense in some other technology than OLED.

Scale Models

I was excited about creating lights in the edges of the rooms and the next step was to construct a scale model of a room corner out of cardboard. This would serve as a base for experimenting with paper models (Figure 41). I made several attempts in shaping a ceiling corner light with single-curved surfaces. My aim was to have a knot or a multilayered spline construction in the corner that would be the beginning of a lighting

Figure 41 - Scale models of single-curved ceiling corner lights.

system that would encompass the illumination of the entire room. Stylistically this was challenging and after a while it seemed pointless to go for a complex shape for only the purpose of decoration.

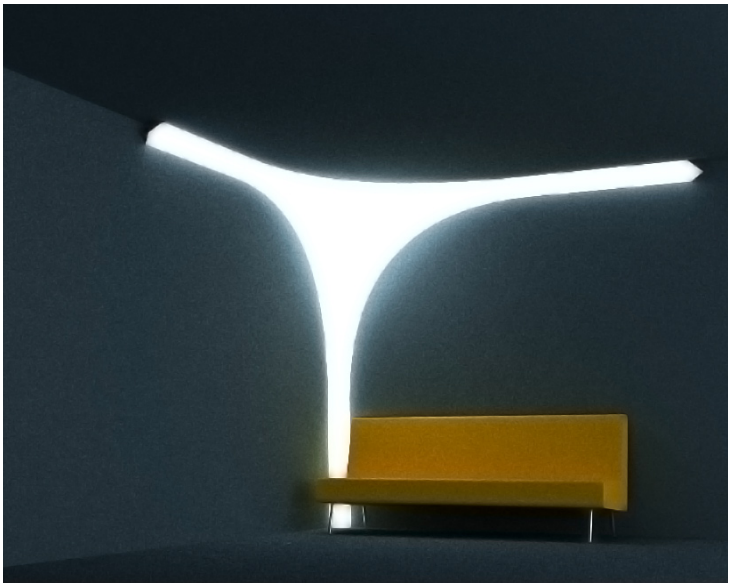


Figure 42 - Peripheral lighting.

I simplified my approach and returned to the original cubic edges-and-corners idea. This time, I did my best to keep the shape single-curved and to avoid excessive roundness. I designed a corner light that was based on a triangle in the corner and three strips that extend from the triangle's sides along the edges of the ceiling. The aim was again to populate the normally dimmer areas of the room with light sources and to create a soft light in the room. The result was calm in appearance and one that would effortlessly fit many different architectural spaces.

Scaling Down

I was pleased with my ceiling corner light design, but it occurred to me that a sheet that hides an empty space behind it and illuminates a room might just as well be a diffuser to another kind of light source. A translucent opal panel in front of a fluorescent tube or an array of white LEDs would do the same trick. I realized that as much as I liked the design and wanted to experiment with this kind of spatial illumination, it wasn't the kind of approach that was going to exploit the unique benefits of OLED technology. In this dead-end of an ideation process, I had to make a U-turn. Back in square one, I gave deep thought to what the nature of OLED really is. It is light-weight, thin and supple. It remains at a cool temperature and can produce a smooth diffuse light in a tighter space than any other lighting solution. From a user-centered perspective, these attributes all point to touch and proximity. If I was going to make a bold prediction about the future of OLED lights, I would say that their most prominent use will be in task lighting, not in general lighting. General lighting often has the luxury of empty air space that can be used to house diffusers, reflectors and mountings. A hanging ceiling light won't become much better if it loses five centimetres of thickness, but a desk lamp will. Bending a light in the ceiling makes little sense, but a reading light that can be shaped according to needs does have recognizable benefits. In spaces that often are tight, such as kitchenettes and car interiors, a flat smooth light will contribute to the economical use of room.

The much-talked about and intriguing feature of transparency in an OLED bears the capability of completely transforming a space or an object, but the uses of such a capability aren't altogether obvious. Besides making windows that can turn into lamps, the actual practical applications of that possibility are difficult to come up with. Even in OLED windows, there's a trade-off that's rarely mentioned. Transparent OLEDs aren't completely transparent because they have to contain a certain amount of metal to be conductive. In fact, one ambitious plan from Taiwan-based display manufacturer Winstar states that they will produce 50% transparent lighting panels by the latter half of 2013 (Mertens 2012). Losing half of what makes a window a window is a major loss that only very large office windows or transparent interior space dividers can afford. I believe that there are many uses for transparent OLEDs but that most of them are in display technology. In practical lighting design, it is a very specific case of OLED application and certainly merits designer contributions.

A Floor Light

I took as my new starting point the smaller-scale light that was going to physically be closer to the user. In this way, I believed that more of the benefits of OLEDs can be met. Using EL-sheet allowed me to choose whatever size I wanted for my prototypes and I didn't want to be restricted to the scale of contemporary OLED panels. What I had in mind was a multipurpose light that can be adapted to work as a task light as well as a general lighting supplement. Quite quickly I realized that a standing floor light would be the best choice for a light that can come close to the user as well as remain farther away. It is a light that benefits from being bent and twisted. Even an adjustable brightness would fit naturally a luminaire that has multiple uses. Both practical and decorative, a floor lamp would also benefit from being thin as opposed to thick and clumsy.

Having used fluorescent and incandescent lamps in my desk lights in the past, I also believed that a smoother and wider light source could reduce the sharp shadows that are cast by hands and pens when working at a desk or when reading a book. I quickly made some sketches of a standing light strip that could perform the tasks I had in mind for it. The initial ideas are not very different from the final results.

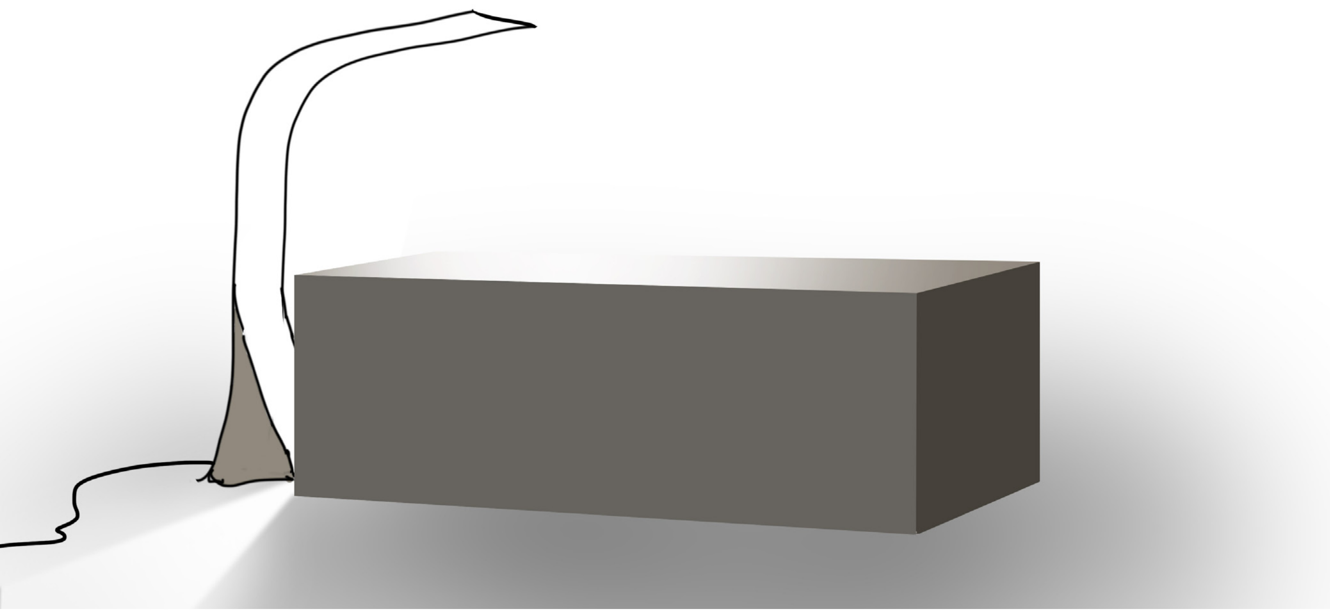


Figure 43 - An early sketch.

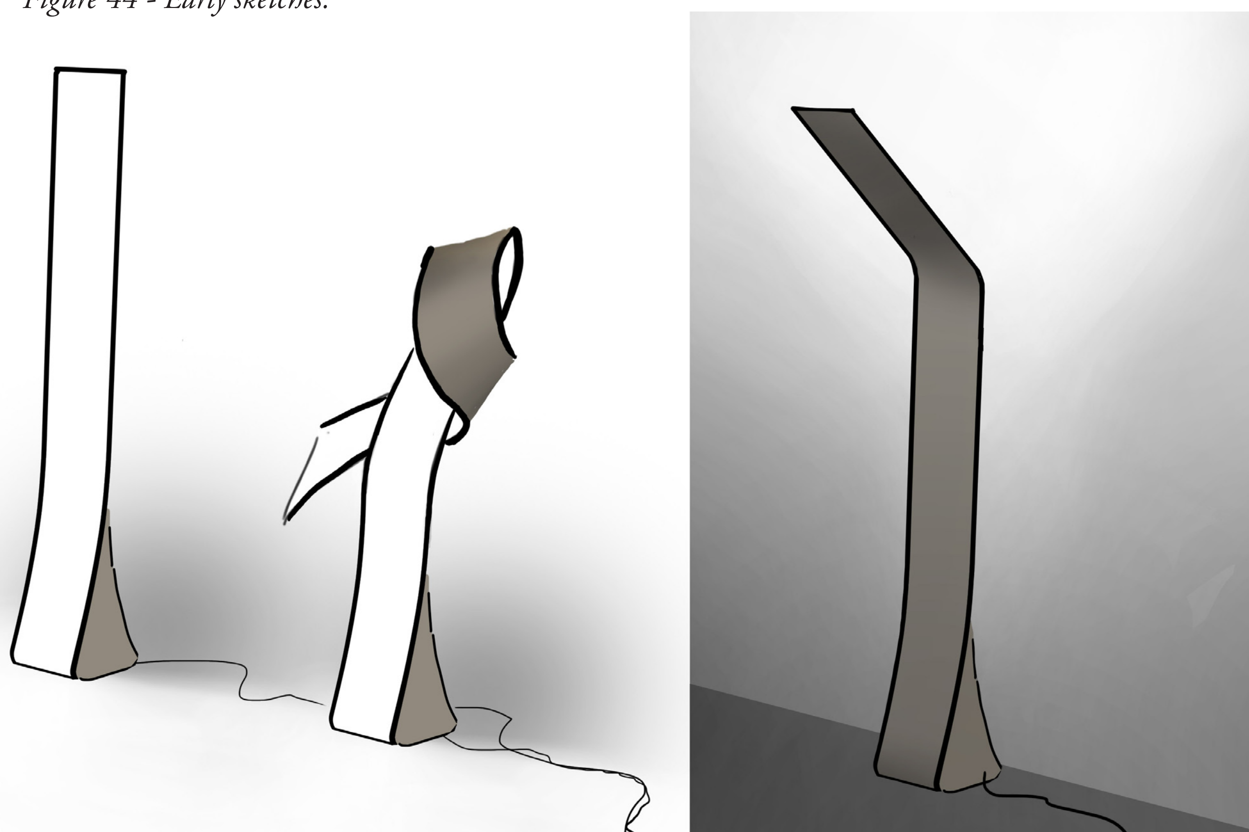
A very determining characteristic in a light such as the Idleply is its height. I wanted the highest point of the luminaire to be above most people's eye level. This way, if desired, the illuminated side can be kept completely out of view even if the luminaire is slightly bent. When aiming the light at walls instead of the open space, this can come in handy. Average male height in Finland is from 179 to 181 centimetres and eyes are located some 15 centimetres below that height. I decided to give my luminaire a height of 180 cm to make sure it safely exceeds average eye levels. The other aspect of height was that the lamp had to be able to bend over a desk and give it enough coverage to provide a smooth light. 180 cm was quite enough to do that.

To further accommodate the light to the needs of the desk worker, I decided that on one side, only the upper half should light up. I believed that a full-length light might be disturbing and moreover, a waste of energy in a situation where light is only required above table height. The difference between the sizes of the light elements eventually led to distinguishing their respective two switches with a corresponding size difference.

The overall style of a light that's based on the latest technology is too often also technological. Despite having technology as a starting point, my most central theme in designing Idleply was usability. I wanted to stay clear of the kind of techy styling that will put many normal users off. Instead of carbon fiber and aluminium, materials such as textile and wood are more approachable. Instead of futuristic or aerodynamic high performance form languages, simplified shapes are more interior-friendly. Natural materials and soft shapes do not contrast with advanced technologies but rather complement them by adding the element of life and humanity into them.

A hanging light can be complex and decorative in its shape, but a desk light and a floor light has to have a functional approach. They are turned, twisted and moved around by the user and are always very physically interactive. I aimed since the beginning to keep my work minimal in expression and focus on the requirements of usability. It was the foot of the luminaire that had the most to be thought about in terms of shape, material and size. I went through many different ideas. Some of them had a minimal amount of material, others were troublesome metal casings with intricate kinks. The main challenge was to articulate a transition between the space that had to be occupied on the floor to keep the light standing, and the slim rectangle from which the spine of the luminaire would start. The foot had to be strong enough to support heavy twisting and it had to contain some kind of switches to turn the light on and off. It was again the functional approach that prevailed in the end. A rather simple curvy plastic casing

Figure 44 - Early sketches.



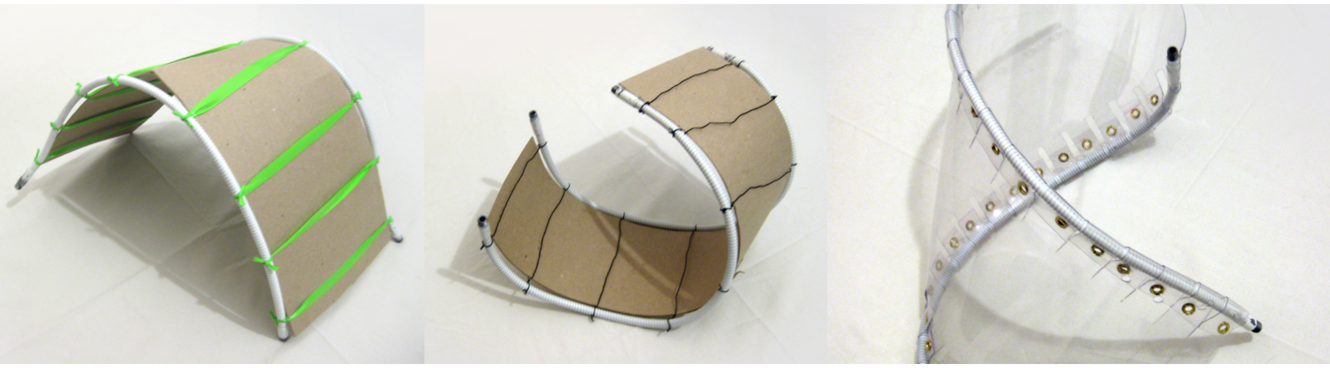
could support the shape and conceal the electronics effectively. It was also a straight forward way of transitioning from large square to slim rectangle. I initially thought that the plastic casing could be strong enough to fully support the heavy upper part of the light but later ended up downgrading the plastic part to just a casing that conceals the wooden supporting structures. The shape that I ended up with is reminiscent of a lot of design that in the 60's and the 70's explored the possibilities of plastic. Those shapes may once have seemed futuristic but they certainly aren't that today. A round and curvy plastic form has all the attributes of playful friendliness and attracts human interaction.

I placed two slim metal switches on the same side of the foot. The shorter one turns on the shorter light and the longer one switches on the longer side. The wooden base is visible and the screws that attach it to the plastic casing are visible as well. Towards the end of the building process I decided to give the base a colourful accent in bright fluorescent paint.

MAKING THE PROTOTYPES

After I had settled on a final design, it was time to start putting the prototypes together. To better explore and present the possibilities of my work, I decided to make two instead of only one. The benefit of making more than one prototype is also that you learn from the first process and you can then improve in the second one. There were two big question marks: How was the pliable spine really going to be constructed and how was it going to be attached to the foot in a stiff and steady way? The answer was of course in trying out different approaches in practice.

Figure 45 - Experiments in spine construction.



The Spine

The spine of Idleply is the largest and most central part of how it works and appears. It allows the required amount of rigidity and bendability. Its frame has to withstand stress that comes from the user grabbing it and bending it but it has to be light enough to not knock the balance of the entire luminaire off. The width is determined by the width of the lighting panels. On the sides of the panels, gooseneck tubes covered by PVC and textile parts contribute to the overall width. The thickness is kept to the minimum that is allowed by all the layered materials. The form factor of the spine is a spline shape and the most significant dimension of it is its height. The height of the spine constitutes the largest deal of Idleply's overall height.

Because I was working on a frame that supports a lighting panel that was going to be bendable, I had to construct a frame with edges that would only trace single-curved surfaces but the spine was also going to have to be as thin as possible to minimize wrinkling in the outer layers. Two goosenecks in free space as edges to a surface may trace an infinite number of unsuitable forms, so it was necessary to find a restrictive construction. Basically, the two long goosenecks were going to have to be kept at a certain distance from each other. The most obvious restriction was a bendable

Figure 46 - Gooseneck tube materials.

surface attached between the goosenecks that would keep the distance between them constant. Another approach would have been to weld a ladder-like construction that would constrain the inter-gooseneck distance only at certain intervals. The ladder construction initially seemed attractive because of its strength and the space it gave to other parts but later I went on to discover that the gooseneck tubes required a certain extra stiffness that would make the overall frame construction a touch less supple.

The hunt for long, thin and rigid gooseneck tubes was a difficult one. At an early stage when I realized how challenging it would be to get this material, I ordered some 50cm-long 16-mm thick tubes from a Finnish online store, but already then they seemed unnecessarily bulky. During a visit to a friend's place I noticed a simple LED-work light on her table that featured a beautiful 7mm-thick gooseneck that was about half a metre in length. The light was called Jansjö and was a recent acquisition from a Polish Ikea. It turned out that Ikea lights were not only the most affordable and quickest source of gooseneck tube but perhaps the only one for thin and long tubes. The cost per one metre of gooseneck from a Jansjö light was less than twenty euros when for example, the reliable and often affordable computer supply store Verkkokauppa.com sold a thick 40-cm gooseneck for thirty euros. After I had gotten my hands on eight 53cm Ikea-born goosenecks, I began experimenting with the constraining single-curved bending shape (Figure 45, p.41).

My first tries were with a piece of cardboard and different attachments to it. The iron wire approach worked well, but proved impossible to recreate once I had moved on to using a plastic sheet. It is easy enough to attach a piece of plastic to a tube, but here I had to keep the material close, the angle perpendicular and allow a freedom of movement at the same time. After some experimentation, I ended up using metal eyelets (4 mm hole) to attach smaller strips of plastic to the edge of the larger sheet and around the gooseneck tube. At this point I had the goosenecks welded together to form long continuous tubes.

After the most central structure of plastic and gooseneck was ready, I made it more rigid in one end by sliding some spring steel rods into the gooseneck tubes and right beside it on the inside of the plastic strip wrappings. Spring steel allows bending and will spring back straight. I also slid an electrical wire from one end of one gooseneck to the other for powering up the shorter EL-sheet. Once this was done, I could cover the frame in stretchy off-white fabric to conceal all the metal and plastic. I first glued the EL-sheets on to the fabric, but they hung slightly loose because of the stretch of the textile. I had to sew them on. Using the eyelet holes inside as passages through the structure, I was able to both attach the sheets firmly on the spine and hide most of the string. Later I learned that the EL-sheet had to be insulated with plastic to prevent electrical shocks as now many unsealed edges were left exposed.

The Foot and the Casing

It was important that the foot is strong enough to withstand the bending of the spine and wide enough to keep the luminaire from falling. I chose to build a wood and steel construction on the inside of the foot and cover it with a plastic casing. The plastic would only be for protection, cosmetic effect and for attaching the switches to. The wooden part is made of different thicknesses of plywood and metal parts that hold them together very firmly. The spine is attached to the plywood boards with screws and metal wire.

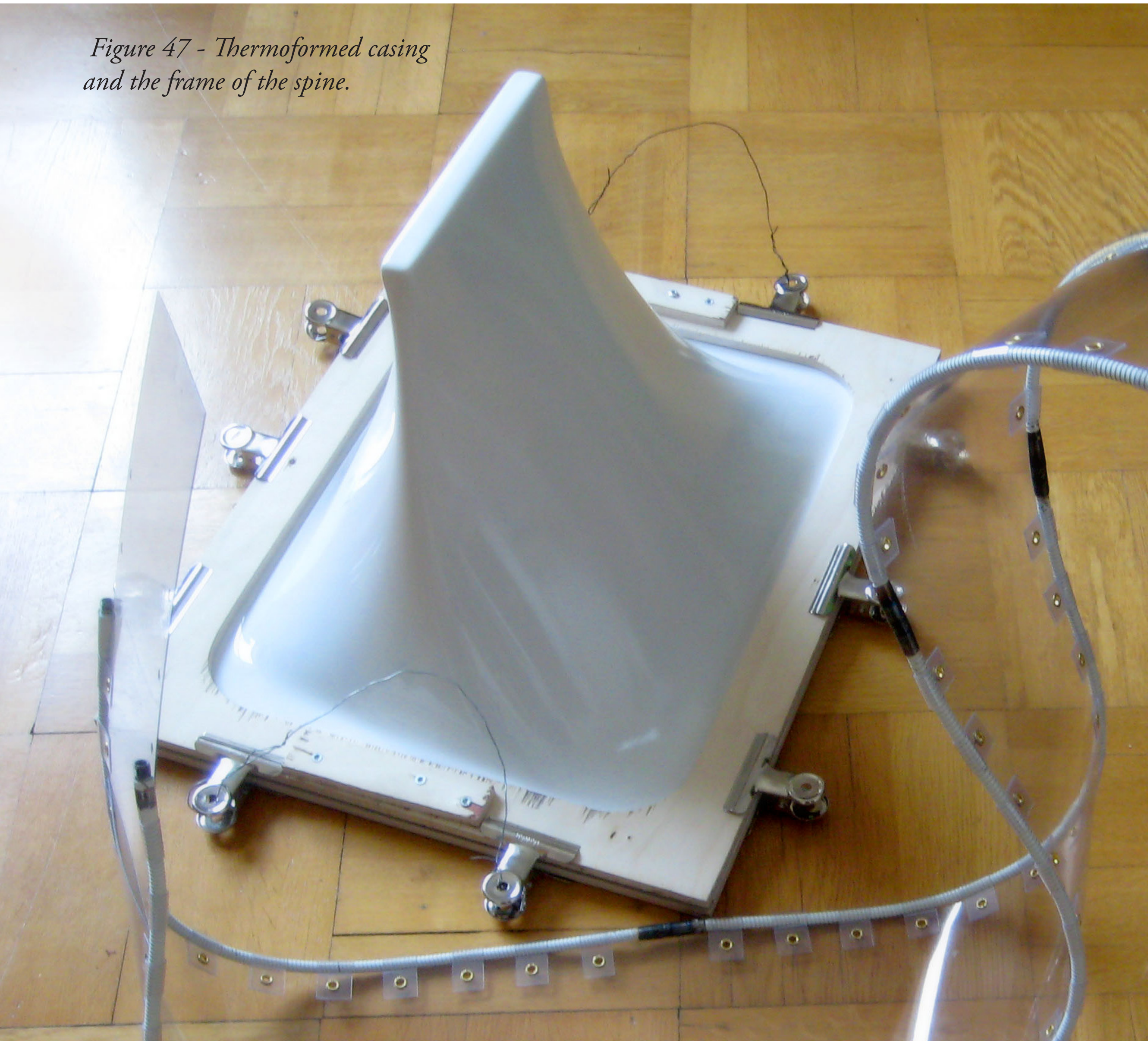
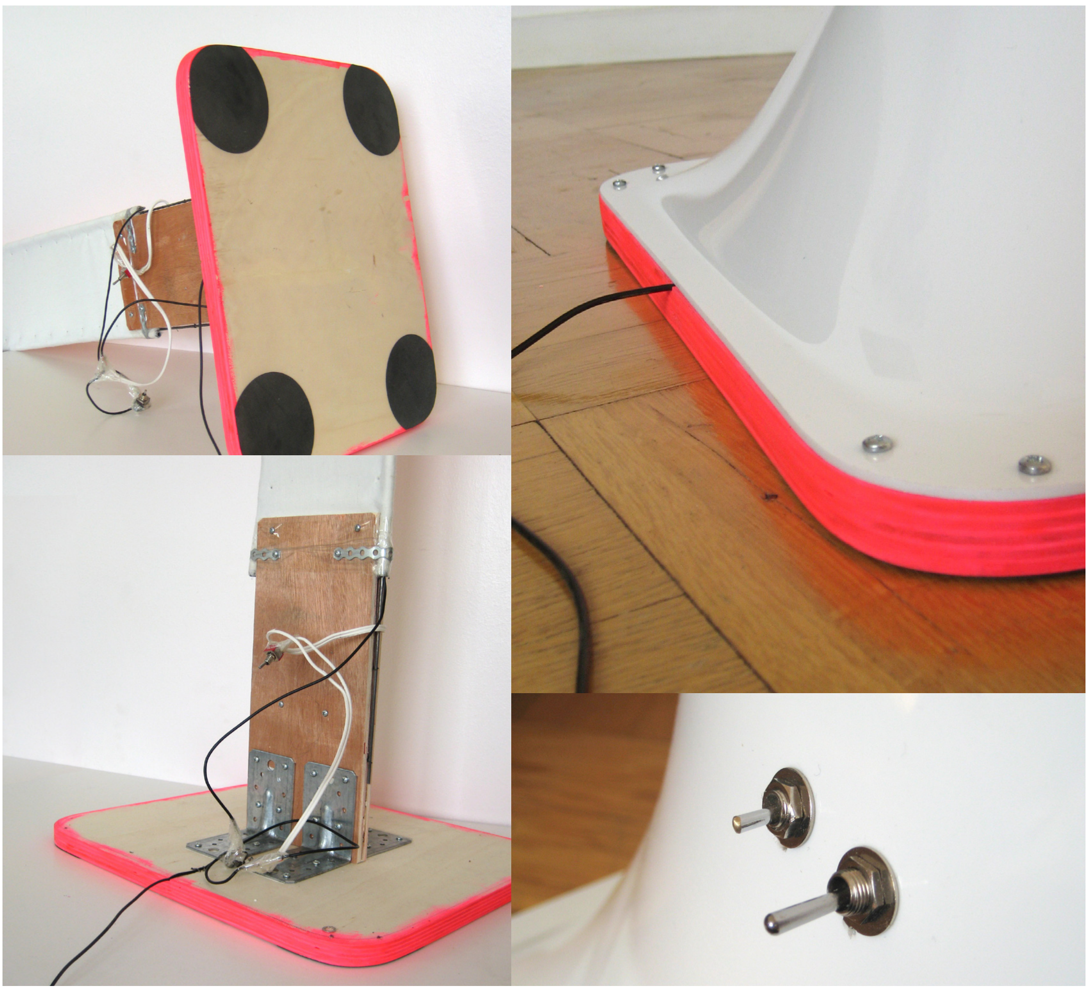


Figure 47 - Thermoformed casing and the frame of the spine.

Thermoforming the plastic casing was a challenging task. I squeezed the 3-millimetre polystyrene sheet between a two-part frame with large paper clamps. The hole in the frame left a large portion of the sheet exposed. When heated under the heating elements of a vacuum forming machine, the sheet started to slack and soften and became ready for manual forming. I then took out the frame with the sheet still attached to it and pressed it against an upright plank to produce the protruding form that leads to the spine. I first tested this procedure at home with a gas stove and then redid it several times with the proper devices to get the form right. As it is a manual process, results varied every time and the very stretched and steep form took many attempts to remain thick enough.

To add a touch of colour, I painted the only visible plywood part with a bright red colour and finally attached rubber pads to the bottom.

Figure 48 - Details of the foot.



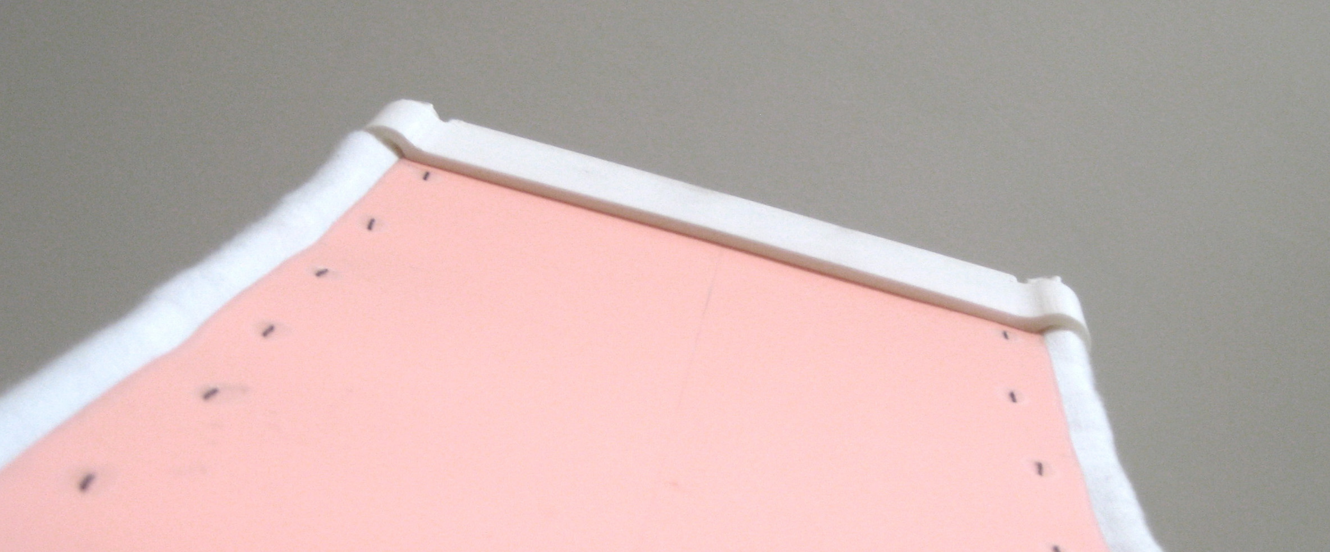
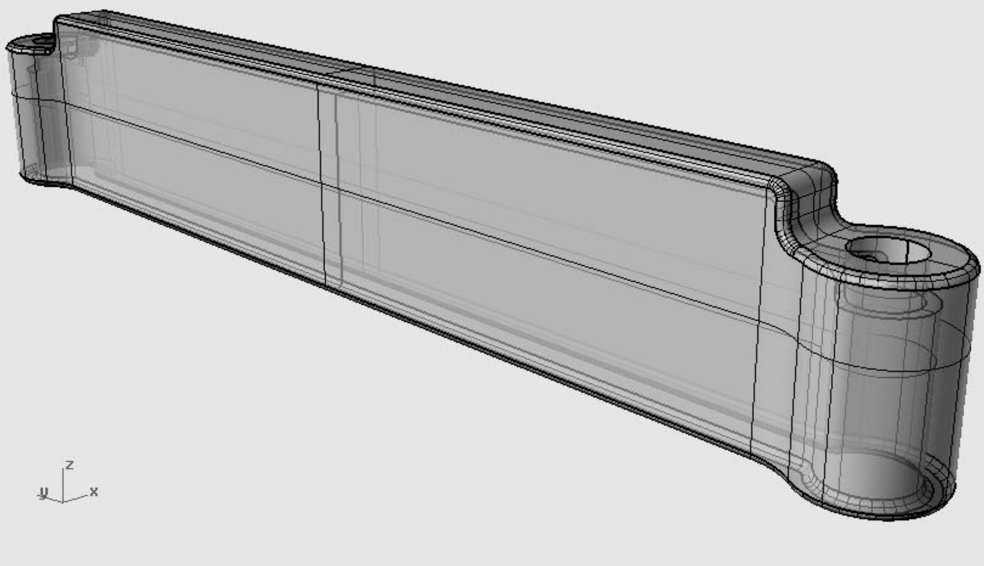


Figure 49 - The EL-sheet is tucked under the plastic head part.

The Head

On the very top of the lamp sits a plastic part that covers an electric wire and the top ends of the two EL-sheet strips. It also provides a place to grab a hold of when manipulating the shape of the lamp. It is a rapid prototyped part made of ABS plastic, designed in Rhinoceros 3D. The shape is a result of keeping the head as low key as possible. Because the gooseneck tubes have to be bolted onto it to ensure a solid attachment, the smallest-size option was to leave the nuts visible and have their height and width repeated by the plastic bit. The metal nuts were covered with adhesive plastic for insulation and the whole head was painted with a white paint.

Figure 50 - The head was modeled in Rhinoceros 3D.



MATERIALS USED

Electroluminescent Sheet

In making the prototype, I decided early on that I'd use electroluminescent materials for making the illuminative parts instead of actual OLEDs. Although electroluminescent materials aren't nearly as bright as OLEDs, they have a number of advantages when it comes to illustrating future possibilities of organic light-emitting diodes. All available OLED modules are flat and rigid and their form can't really be altered by the experimenting designer. Most OLED modules that can be bought are either squares or rectangles, further restricting creative freedom. Lumiotec and OSRAM (Mertens 2011, p.43) manufacture OLEDs in the non-quadrilateral shapes of circle and octagon, which can hardly be mistaken for unlimited creative freedom in lights design.

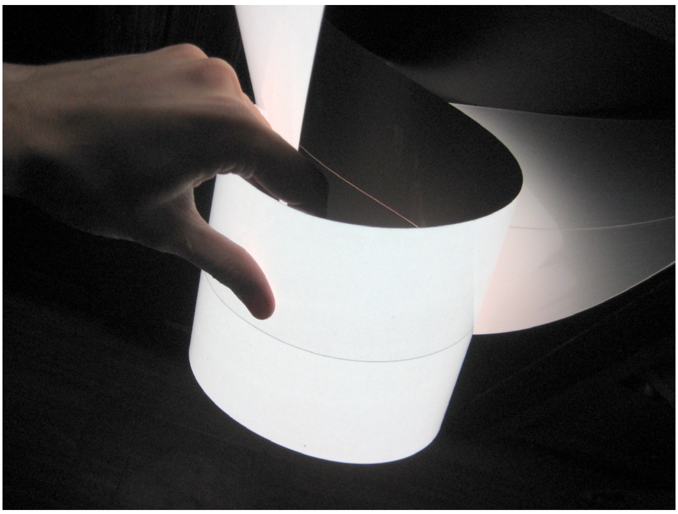


Figure 51 - 6-inch Flatlite split electrode EL-sheet.

It is acceptable to design light fixtures for the standardized light bulbs as we know them but as OLEDs have yet to achieve a normative standard size, shape or material, designers are required to look beyond what is available right now, especially when designing concepts for the future. When making prototypes for these future concepts, compromising creative vision for the sake of available technology isn't acceptable. For me, it was necessary to abandon the idea of using OLEDs in prototyping, because it appeared already at an early stage that the features that I was most inspired by hadn't made their way out of manufacturers testing laboratories. I wanted the light surface to bend in curves or even achieve completely freeform double-curved shapes.

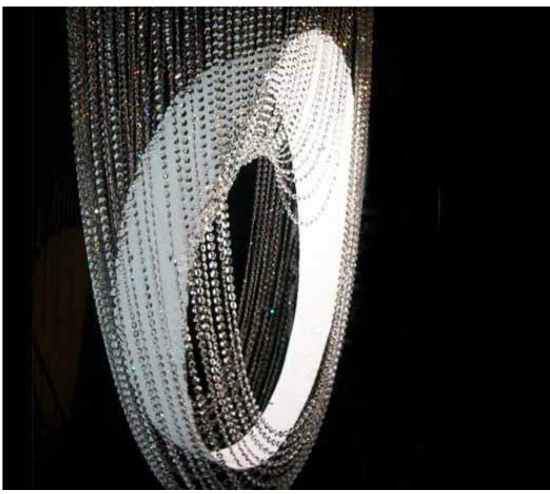
Thin electroluminescent sheet materials that can be cut to shape, bent and folded have been available to consumers since the year 2000 (Home & Lighting Accessories 2005, p.92) and even electroluminescent ink shortly thereafter (DuPont 2006). Electroluminescent ink would theoretically allow designs that manifest wild shapes of any kind, but the process of laminating even coats of different materials is a very complex one. The task of producing only a few square centimetres of rigid flat surface is a tedious one that requires patience and care (Ellsworth 2010). In the wildest iterations, I was planning to create several square metres of freeform light surface and electroluminescent ink clearly wasn't the way that was going to be achieved.

The best way to achieve thin light-emitting surfaces for prototyping and for demonstrating the possible function of an OLED luminaire turned out to be the electroluminescent sheet (EL-sheet). I found and contacted companies online that sell different sizes and colours of sheets. Of those contacted, Elec2go is an Australian company and Electro Luminescence Incorporated as well as LuminousFilm operate in the USA. LuminousFilm had the longest history, the widest selection and had even collaborated on a Swarowski crystal project (Figure 52) with industrial designer Yves Béhar of San Francisco-based design company Fuseproject (Gallion 2005). In the Swarowski project, the original idea of using OLEDs was abandoned due to extremely high cost.

Fuseproject has also used electroluminescent sheet in their InnerLight concept piece that was designed for a Fuseproject show in SFMOMA (Figure 54). Japanese

Figure 52 - EL-sheet in the 2005 Swarowski chandelier Nest.

Figure 53 - Archimede's Dream by Makoto Tojiki (2007).



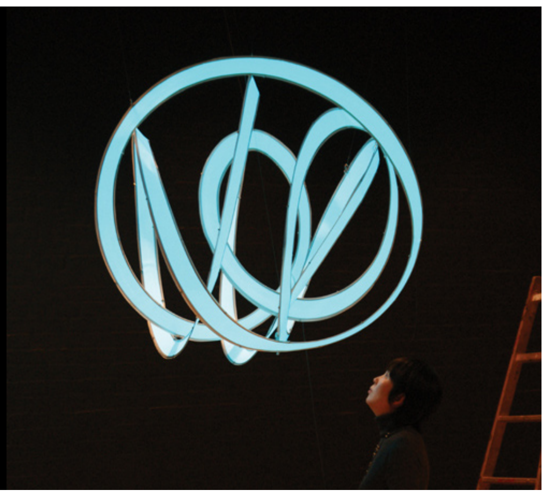
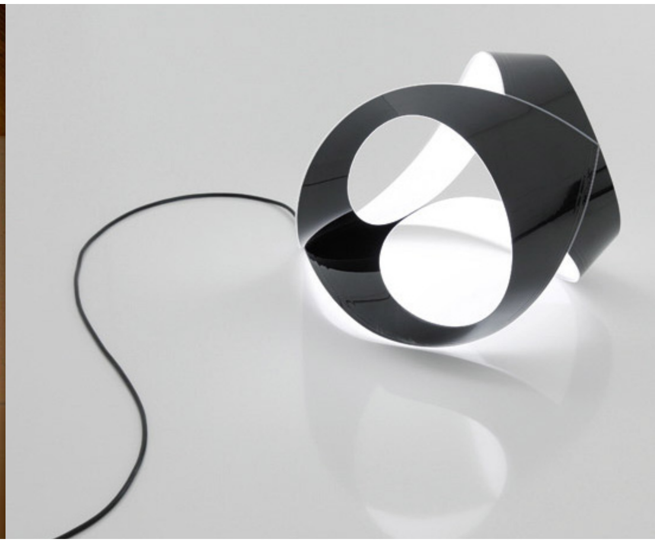


Figure 54 - InnerLight by Fuseproject (2004).

Figure 55 - Perelin by Markus Becker (2009).



artist and industrial designer Makoto Tojiki also opted to use EL-sheet in his sculpture Archimede's Dream (2007) in order to illustrate the potential of OLEDs (Figure 53). In addition to one-offs and art pieces, there have been attempts to sell electroluminescent lights as commercial products. One such example is the 2009 EL-sheet luminaire series Perelin by German designer Markus Johannes Becker (Figure 55). This beautiful product has won awards for its innovative use of the EL material, but it undoubtedly fails to be a very bright light.

Figure 56 - The Cevanna Smartdrive SD2400AC inverter.

From LuminousFilm.com, I purchased 7,5 feet (228,6 cm) of 6-inch (15,24 cm) wide Flatlite split electrode EL-sheet per luminaire. The material has a cool color temperature of 5400K, which is close to daylight, although brightness and color rendition are poor. LuminousFilm states that the surface brightness of the panel, operated at 250VAC and 650Hz, is only 54,66 cd/m^2 (LuminousFilm 2008). This isn't much compared to desktop displays (250-300 cd/m^2) or the OLED light modules that are available (1000 cd/m^2) but with a sufficiently powerful inverter this brightness can be doubled, although increasing the brightness will negatively affect the sheet's half-life. With the recommended voltage and frequency, a Flatlite panel will degrade to half of its brightness over 8000 hours of use, but it will never completely die out. The decay of brightness levels depends on the grade of phosphors used by the manufacturer, the manufacturing methods employed, the temperature that the panel is used in and the power settings applied by the user. It is difficult to predict how much quicker the panel will grow dimmer if a certain amount of extra power is applied.

The most obvious downside of using EL-sheet to illustrate OLED is its lack of brightness. In the right conditions however, this is negligible. If not used during daylight or in well-illuminated spaces, the brightness of properly powered EL-sheet is quite enough to create a convincing demonstration of the potential uses of OLEDs. Luminances on directly visible surfaces, such as displays and ambient OLED lights, should anyhow be limited to less than 500 cd/m^2 in order to avoid glare.

Shortcomings that aren't apparent in photographs are a slight reddish texture on the surface of the sheet and a faint high-frequency buzzing noise. The texture is only apparent from a close-up distance and the buzzing sound is easily masked by other noises in a non-quiet environment. The biggest problem of the three is the noise as it greatly limits any practical uses of EL-sheet lamps. A typical home office isn't plagued by masking noises that would hide the annoying buzzing. And although the external inverter can be easily soundproofed with a heavy box, some of the buzzing comes from the sheet itself and becomes louder with any increase in brightness. The inverter that I purchased from LuminousFilm called Cevanna Smartdrive SD2400AC (Figure 56), has an output frequency of 610 to 675 Hz, which is well within the audible range of sound. The sound that comes from the light is an effect of the sheet resonating with the AC current that is passed through it at that frequency. I speculate that using smaller sheets and less power could reduce the sound to a quiet enough level for an EL light to be used in silent conditions.

In addition to the functional electronic aspects of EL-sheet, its other material properties are very suitable for prototyping OLED luminaires. The split electrode Flatlite EL-sheet has layers of metal, plastic and phosphors, the external ones being metal on the back side and plastic on the front. The sheet is very durable and reliable. It can be bent, folded and punctured quite violently without rendering it dysfunctional. A sharp fold can't entirely be flattened out, but it won't break the sheet either. Holes and cuts have virtually no damaging effect on the functionality of the sheet. The instruction manual does, however, advise against folding along the center line and cutting from the side all the way to the center line. Neither of the electrodes that each run the length and occupy half the width of the panel can be cut in two as this would cut the flow of the current. It also appears that cutting an electrode to a very narrow width anywhere on the sheet will cause the rest of the sheet on the other side of the bottle neck to light up dimmer.

Without proper insulation, there is a risk of electric shocks from the panel. Having suffered several shocks, I am proof that they are neither deadly nor dangerous to healthy regular individuals. However, they are very uncomfortable experiences and any holes, cuts or even unmodified edges that can be touched should be sealed with tape or adhesive plastic film. The electric shock will happen if a person comes into contact with both electrodes at the same time. Most easily this is achieved by touching both halves of the back side of the panel where the electrodes are exposed. Anything that goes through the panel, such as a thread, should be sealed even if it isn't metal because a perforation may always expose edges that lack insulation. In my prototypes, I opted to cover the entire EL-sheets with large adhesive plastic films to insulate the perforations as well as the edges in a clean and invisible manner.

Electroluminescent sheet is somewhat of a marginal material in lights design and prototyping because of its lack of brightness. For some interior uses and outdoor advertisements it is ideal and it has been used in festive decorations as well as cinema interiors. Wherever it is dark and flat lights are needed on walls, ceilings and floors, EL-sheet is a good choice. It has been marketed as an easy-to animate choice for advertising. Relatively thin animated and illuminated posters can be made with EL-sheet, but the animations tend to look clumsy and silly in the modern world of iPads and thin 55-inch television sets. As a backlight for posters, it requires transparent prints and will still be dimmer than poster installations that house fluorescent tubes or LEDs. Perhaps in the future EL-sheet will be widely used as a less expensive material to explore OLED light designs in the same manner as I have done in my project.

Gooseneck

Gooseneck is the tube material that is commonly found in microphone stands as well as many table and floor light fixtures. It allows bending the luminaire into all sorts of shapes. It is a deceivingly simple double helix construction of two intertwined metal spirals. The inner spiral has a round profile and the external one a triangular profile (edge pointing to the inside of the tube). As the tube is bent, the triangular profile becomes wedged between the round loops of the inner spiral. On the inner side of the bend, the triangular profile is pushed outwards as the gaps between the inner spiral's loops tighten while on the other side it is being pulled inwards and wedged. The constant contact and pressure create a powerful overall friction that makes the tube remain in whatever form it is bent to.

Gooseneck lights first appeared already in the early decades of the 20th century in early modernist luminaires as well as art deco work lights. The material has not significantly evolved during the century that it has been available and its characteristics still are unique. Only some very recent plastic products like the Gorillapod made of high-quality ABS, and engineering plastic Surlyn by DuPont (Lefteri 2006) have rivaled the performance of metal goosenecks.

Gooseneck as a material isn't widely available to consumers, or at least the selections are very limited. It is recommendable to anyone looking to get their hands on some prime gooseneck to scavenge affordable luminaires rather than buy the material itself. Ikea is a good resource for slim tubes of gooseneck.

Other Materials

Other used materials are more basic. There are two types of plastic: polystyrene and polyvinyl chloride (PVC). White 3 mm polystyrene sheet was used in the thermoformed lower part of the luminaires and different thicknesses of transparent PVC sheet were used in the internal structures of the long spine part. A thicker sheet of 0,7 mm runs the length of the pliable part to keep the two goosenecks at a constant distance from each other. Small slips of 0,5 mm PVC sheet fasten the goosenecks to the large 0,7 mm sheet. The structure is covered in off-white cotton fabric.

The polystyrene casing is attached with eight screws to a 13 mm thick plywood slate. At the bottom of the slate, four rubber pads soften the floor contact. Inside the casing, two thinner 7 mm plywood boards keep the spine structure up, aided by four heavy angle irons. Some iron wire and perforated steel strip were added to make the attachment stronger.

There are 90 cm long spring steel rods inside the spine structure that make the spine more rigid in the lower end. Each prototype contains four 3,2 mm rods and three 1,95 mm rods. Some are higher up than others inside and beside the goosenecks to make the transition from stiff to pliable as smooth as possible.

The electrical wires that I used are actually stereo cables for music. I chose this type of wiring because it is evenly round and small enough to fit inside the gooseneck tubes. The switches are guitar pick-up switches that have a more appropriate minimal look than any standard household appliance switch. The jacks are the 3,5 mm standard audio jacks that come with the stereo wires.

The head, or the uppermost plastic part of the light is a 3D-printed acrylonitrile butadiene styrene (ABS) plastic part. The head and the plastic tape insulated nuts on it are painted white.

VIDEO

To give a better idea of how the lights work, I've shot a video. It can be viewed at https://vimeo.com/39767843.

Figure 57 - Still image of the video featuring myself and the two Idleply lights.

Discussion

RELEVANCE TO RESEARCH QUESTIONS

In the introduction, I outlined the research questions that I was seeking answers to. As is normally the case with any research, definitive and final answers are rare. The questions served as a guideline and helped in keeping a focus on relevant issues. The following paragraphs are a revision of how each of my research questions was answered.

How can a design perspective contribute to the development of OLED lighting? The project has strengthened my belief that designers should push the development of technology in directions that are not only determined by laboratory scientists. Too often designers are only commissioned to “do something cool” with given branded components to promote a company’s current product. This question wasn’t in a very central role in my thesis project but it has given me perspective on the role of designers.

What kinds of new possibilities does OLED technology give to lights design? This was perhaps the most important and relevant research question I had. Answers to this question can be found on most pages of this publication but in short, OLED enables an entirely new form language in lights design and places completely new challenges, too. How lights manufacturers will balance between the novelties of both form and function will be an interesting quest to follow.

What are the biggest practical benefits of OLED lighting? This was a functional starting point in the design work. I wanted my luminaire to reflect real-life benefits outside of the obvious aesthetic advantages. The biggest and most widely applicable advantages are energy-efficiency, glare reduction and thinness. Transparency and the ability to bend are advantageous in a smaller number of cases.

What are the limitations of OLEDs in designing lights? I used this question to rule out the approaches that I wasn’t going to take. OLEDs aren’t very suitable for outdoor lighting. The wide dispersion of light would make OLEDs less efficient than lights that can be easily targeted. Also they aren't as powerful as many other alternatives. Creating any kind of sharp spot light with OLED technology would be the doing the opposite of what OLEDs are good for because OLEDs naturally put out a smooth ambient light.

How is OLED positioned in the historical continuum of lights design? This was a somewhat separate question from the rest and I gave it a thorough answer from a technological point of view. How different new technologies have affected lights design in the past is a good indicator of what will happen in the future with OLEDs. This was also a question that I tried to take into account when designing the style and the look for Idleply. A futuristic and technological look is always bound to become dated in a short period of time, as has been the case with many halogen light fixtures.

BROADER SIGNIFICANCE

In the best case, a good design can evoke interest towards new things. If made well visible and perhaps written about and publicized, an inspiring design can draw the public to learn about promising technologies. I didn't attempt to make a public fuss about my work, but it was displayed in the Masters of Aalto 2012 year show and certainly got a lot of people asking questions. I wish that others will learn from what I have done in my thesis and that my work will be beneficial especially to other designers.

On a personal level, I've learned a lot about OLED technology and lights design in general. I now have a good grasp of how certain kinds of lights are designed and I feel interested in continuing with designing lights in the future. During the thesis process, I had to abandon many ideas I felt good about and just leave them on the drawing board to wait for another day. If I find the time, I definitely have a lot of ideas to work with.

LIMITATIONS AND HOW THEY CAN BE ADDRESSED

No work is ever finished and improvements can always be made. Idleply is not without its share of shortcomings although I am happy with the concept and I feel confident in the rationale that led me to it. It is in the execution of the concept where I find room for improvement.

First of all, I wish I had been able to use real OLED panels instead of brightness-challenged EL-sheet. While it isn't a realistic goal to build a design such as Idleply with actual OLEDs as a thesis project, the outcome that I now have only almost realistically simulates OLED lighting. Also, I've found it difficult to explain the difference and the purpose to people who've never heard of either technology before. Working with the OLEDs that are available would have given me the chance to learn hands-on about the technology but I would have risked doing a much smaller and a more conventional design.

Some details on the prototypes look less than professional from up close. The EL-sheets creak a little and the sewing doesn't always follow a straight line. If bent to certain kinds of forms, the sheets may bulge a bit in unexpected places. In short, the craftsmanship could be improved. In defense I will state that the materials I chose to work with and the design that I decided to pursue were quite unordinary.

I also see need for alterations in some of the design details. For instance, the bending part should be shorter and the stiff part should be longer. That would give the structure more stability and lightness. Extremely long goosenecks have to be reinforced with spring steel to make them more rigid, which in turn makes them heavier and removes most of the bending qualities from the reinforced section anyhow. The best solution would be a non-uniform gooseneck tube that has a heavier gauge in the lower end that would gradually grow lighter towards the top. Even such a bending part should probably be shorter than the ones in Idleply.

The prototypes are not easy to lift and move around because they are quite heavy. Lightness should be targeted more efficiently. Now that I've had the luminaires in my home I have also found that the feet are too large. It is hard to fit them in some spaces and perhaps the style of the feet could also be more minimal.

It is never a challenge to list many things that one is not pleased about in one's own work. I find it more challenging to be completely satisfied with what I've done. Looking at Idleply as a whole, I'm happy with it, but zooming in to certain details makes me want to fix things.

Conclusion

Idleply, as a thesis, is about getting a better understanding about OLED lighting. I have taken a good look at the technical aspects, but mostly my work has been a research of practical considerations. The perspective has been that of a designer's and I've placed a lot of importance on user interaction.

I started by comparing OLED technology to older technologies that once were new and revolutionary and were later adopted for wide-spread use. The reasons why some technologies have been popular in certain applications and others not are almost always practical. Fluorescent tubes are a popular source of light in large indoor spaces because they are efficient, long-lasting and easy to replace - not because they can be manufactured in wild spiral forms. No matter how cool OLED lights may be made to look, they won't become popular until they've proven themselves in everyday use. In certain cases, the advantages that OLED lights offer are more obvious than in others. Idleply illuminates at eye level, but it causes no glare. It can be turned on while you grab and bend it, but it won't fry your fingers. The shape of it is slim although it puts out light on most of its length. All these are qualities that are more difficult to achieve with older technological solutions. Another important feature that should be researched is transparency. Integrating OLEDs into windows has been suggested by many concept designs and could well be a common thing in the future.

It is important for designers to look beyond the stylistic advantages of OLED lighting. Paper thin light surfaces are impressive and inspiring, but only good design can make them useful. Idleply is by no means the conclusive answer to what is the best possible use for OLEDs in future lighting, but it is an attempt at making the most of what a promising technology has to offer. As the technology develops, it will become more accessible and more available and the number of creative OLED designs will increase tremendously. It will be intriguing to see how long it will take for OLEDs to make it into the mainstream and then what shape the lights will eventually adopt.

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Figure 3 *An early Edison light bulb.* Available: http://www.edisonmuckers.org/thomas-edison-lightbulb/. Last accessed 6th Sep 2012

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Figure 17 *A small OLED light.* Available: http://www.oled-display.net/organic-leds-seem-set-to-transform-the-business-of-bulbs/. Last accessed 14th Sep 2012.

Figure 18 *A bendable blue OLED light.* Available: http://www.domusweb.it/en/design/oled-a-technology-of-the-future/. Last accessed 14th Sep 2012.

Figure 19 *Philips Lumiblade Reflections installation (2010).* Available: http://inhabitat.com/reader-tip-philips-special-edition-lumiblade-now-available/. Last accessed 20th Sep 2012.

Figure 20 *Ingo Maurer's Early Future (2008), the world's first OLED lamp.*

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Figure 21 *OSRAM PirOLED (2010).* Available: http://www.osram.com/osram_com/trends-and-knowledge/oled--home/oled-design-luminaires/design-studies/piroled/index.jsp. Last accessed 20th Sep 2012.

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Figure 23 *Victory by Liternity (2011).* Available: http://www.liternity.com/en/lights/carbon-series/victory/clear-lacquer/360-view.html. Last accessed 15th Oct 2012.

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Aalto University School of Arts, Design and Architecture

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